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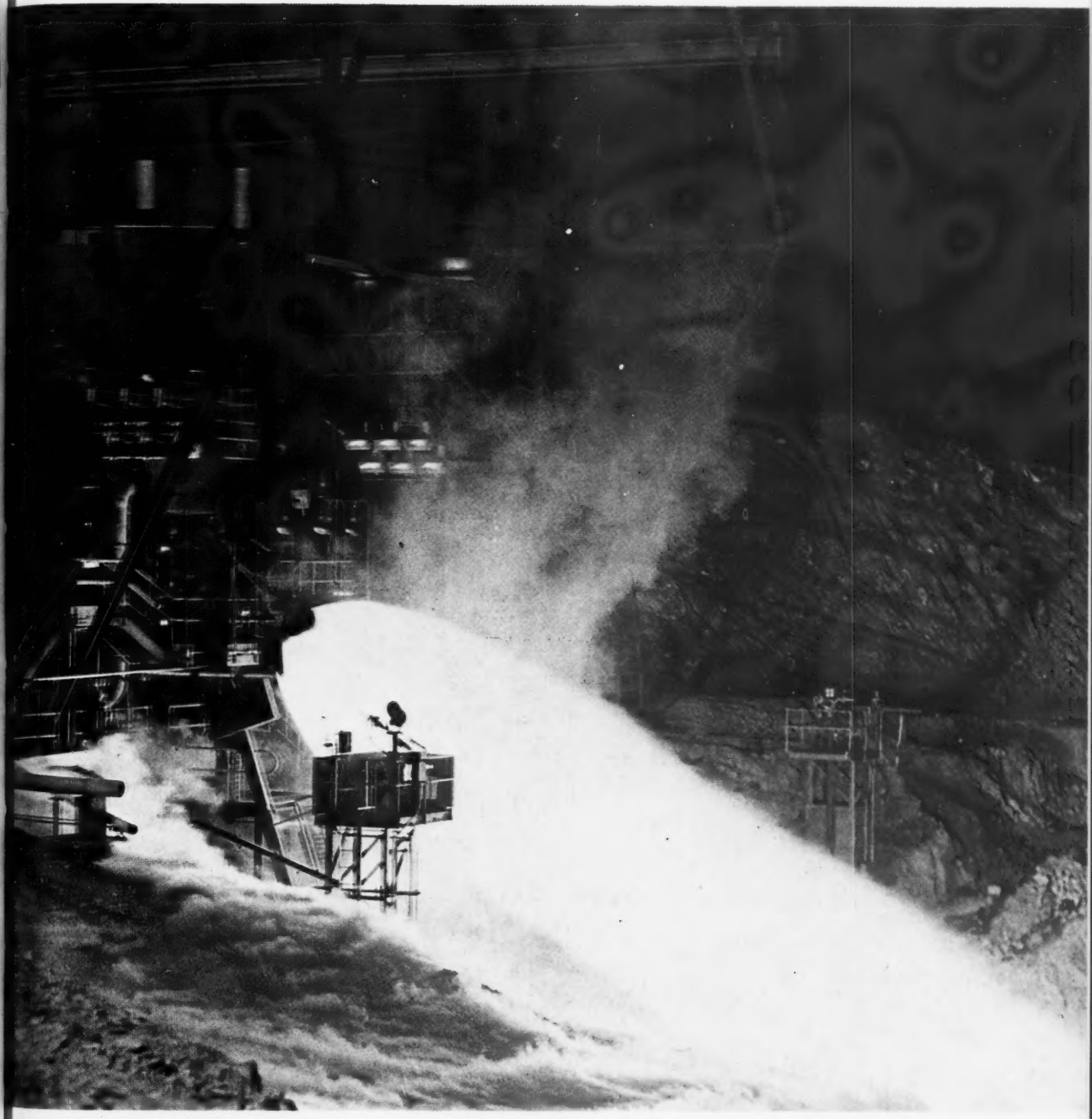
Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

MARCH 1961



SPECIAL SECTION
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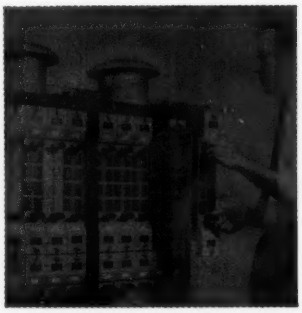

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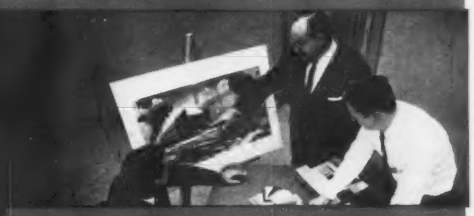

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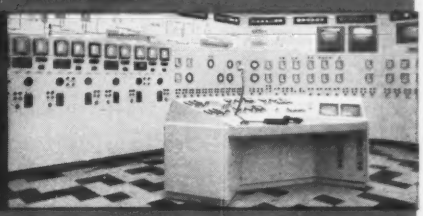

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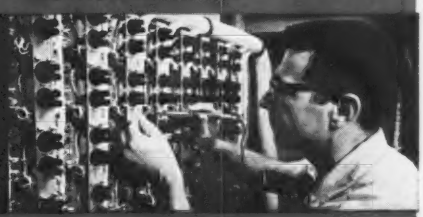

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COVER: Fury of NASA-Rocketdyne F-1 rocket engine is captured in this dramatic photo of thrust-chamber test on Test Stand 2-A at Edwards AFB. Thrust of the engine (see page 24) is about 1,100,000 lb. (ASTRO cover plaques, 11 by 12 in., are available from ARS Headquarters at $2.00 each.)

Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY INC.

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Published monthly by the American Rocket Society, Inc. and American Interplanetary Society, Inc., at 20th & Northampton Sts., Easton, Pa. Editorial offices: 500 Fifth Ave., N. Y. 36, N. Y. Subscription price: $9, foreign $9.50 per year. Single copies, $1.50. Second-class postage paid at Easton, Pa., with additional entry at New York, N.Y.

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The most proven large ballistic missiles, the Atlas (left) and Redstone (right), will launch America's Astronauts. Main-stage engines of both are by Rocketdyne.

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Astro notes

SPACE ORGANIZATION

• The New Frontier found its civilian space administrator in James Edwin Webb, 54, a fast-talking North Carolinian with a formidable administrative background. He served as Budget Director (1946–49) and Undersecretary of State (1949–52), and more recently has been a director of Kerr-McGee Oil Industries and McDonnell Aircraft. He is also a lawyer, a lieutenant colonel in the Marine Corps Reserve, and a former v-p of Sperry Gyroscope.

• The Senate Space Committee approved Webb's appointment in a cursory hearing (after he had promised to divest himself of his space stocks), but his reception elsewhere was somewhat cooler. Critics noted his lack of scientific or technical background and charged that his selection was purely political—specifically, by Sen. Robert Kerr, chairman of the Senate Space Committee, and Vice-President Lyndon Johnson, who is also chairman of the National Aeronautics and Space Council. The critics noted that NASA was the last major government agency to get an administrator and they declared that a number of prominent scientist-administrators refused to take the post because of Johnson's obvious domination of the agency.

• Anyone looking for a clue to the Administration's future space policies would do well to avoid the Space Task Group paper issued early this year. Instead of a polished, well-considered appraisal of the Nation's space effort, the report turned out to be a slap-dash catalog of general, and often inconsistent, criticisms of the space program. This was quite surprising because the chairman of the task group was Jerome Wiesner, who is also special assistant to the president for science and technology. Only two of the nine members of the task group were closely familiar with the space program, and none were involved in its immediate technical problems.

• The momentum of events here and abroad and the plight of the aviation industry point to the Kennedy administration taking the bull by the horns and making the establishment of a manned lunar-landing station a prime objective of national space policy.

MAN IN SPACE

• A second monkey test flight of the Mercury-Redstone system appeared desirable as a result of the unexpected performance of MR-2. While the capsule operated flawlessly, the venerable Redstone turned up a new defect which gave its 37-lb chimpanzee passenger, Ham, a wilder ride than anticipated. Though its flight plan called for an altitude of 115 mi, a distance of 290 mi, a peak velocity of 4000 mph, and a maximum re-entry load of 11 G, it actually attained 155-mi altitude, 420-mi range, a peak velocity of 5800 mph, and a re-entry load of 14 G.

• Responsible for the over-performance was a faulty thrust regulator in the Redstone turbopump. This permitted oxygen to flow too rapidly into the combustion chamber, generating an extra 10% in thrust and velocity. But the motor also burned out 3 sec early, sending the abort signal to the capsule. It promptly separated from the spent Redstone and its escape rockets added still more velocity. The retrorockets, intended to reduce its downrange velocity, were jettisoned as part of the escape maneuver. The capsule executed the re-entry manuever perfectly, but when it was recovered by helicopter and its squealing simian passenger was removed, some 4 in. of water was found inside.

• NASA officials were overjoyed with MR-2's performance, noting that a human astronaut could certainly have survived the trip. But observers felt that another animal flight would be conducted before a man is entrusted to the system. This was partly the result of the niggling but persistent malfunctions in the Redstone vehicle, and partly the result of lingering doubts as to the value of a manned sub-orbital shot, once called a "circus stunt" by Deputy NASA Administrator Hugh Dryden.

• Russia launched what appeared to be the fourth in its series of large spacecraft early last month. It was the largest (14,295 lb) and the most mysterious of the Soviet satellites to date. Its radio transmissions were never reliably received by Western observers, and the Russians declined to discuss its objectives and instruments. Some U.S. observers thought the shortlived satellite might have experienced a power or communications failure shortly after launching. U.S. radar observed the satellite to separate into several sections after attaining orbit.

• Much has been speculated about the newest Russian satellite, usually with shaking lips and rolling eyes. The 7-ton vehicle could well be the first scaled-up version of the Sputnik series that carried two dogs through a successful orbit and re-entry. NASA's Deputy Hugh Dryden suggested it might be an unsuccessful attempt at the Venus launch the Russian's brought off Feb. 12.

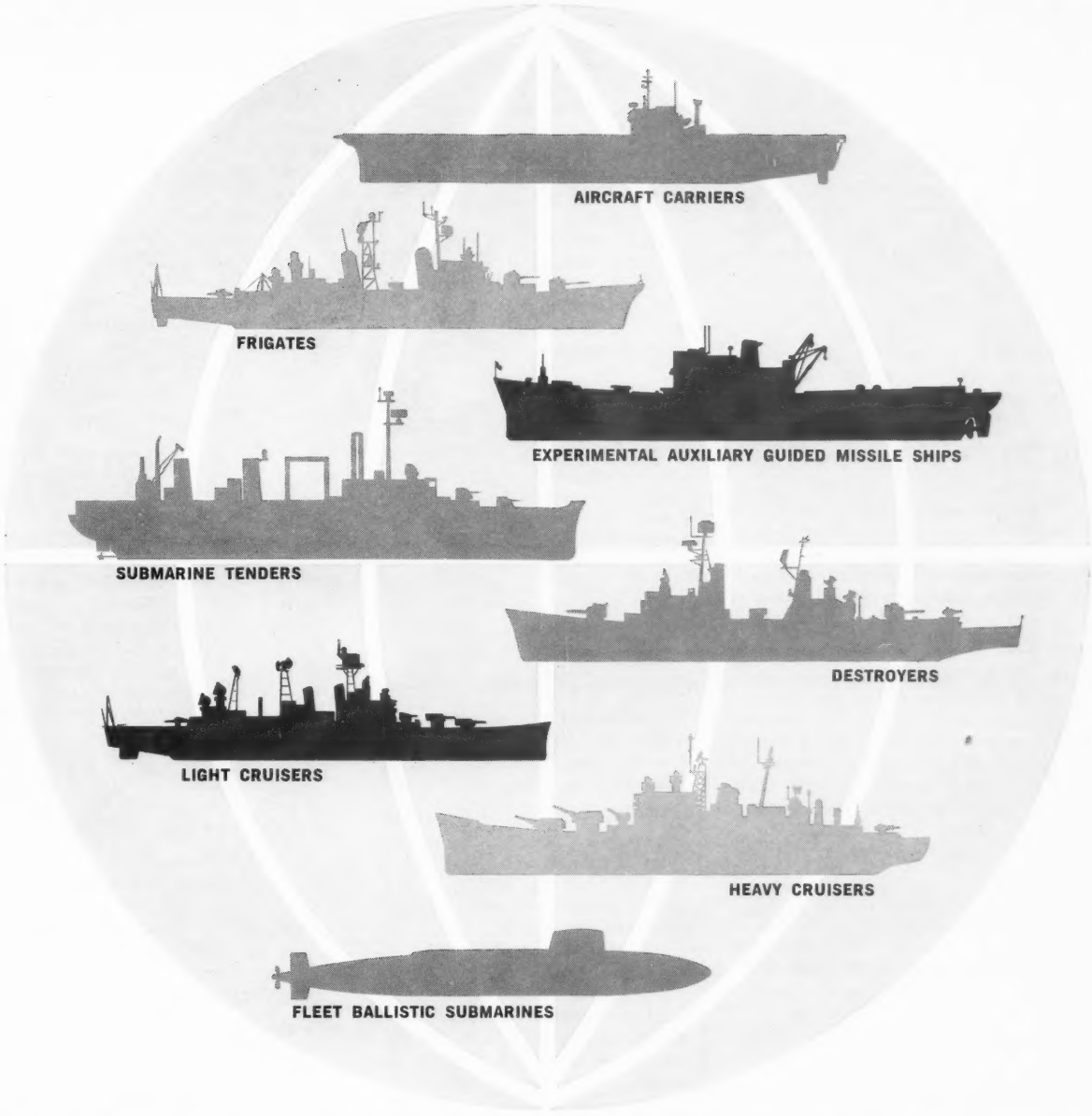
• Radiotelemetry of physiological responses in animals is making important advances. Typical of informed comments on this field, S. England and B. Pasamanick of Columbus Psychiatric Institute, Columbus, Ohio, say that new techniques will permit the monitoring and recording of "selected physiological reactions in intact unanesthetized animals during their normal daily routines in a simulated normal environment, uncontaminated by the intervention of the experimenter or experimental procedures . . ." They report some of their work in the January 13th issue of *Science*.

• The ladies made it. Twelve women, identities not disclosed, have been chosen to take tests similar to those used to qualify the astronauts for Project Mercury. The first astronautress began a series of tests last January at the Lovelace Foundation in Albuquerque.

PROPULSION

• NASA has been reviewing the possible need for more vehicles to be fired in the development schedules for major space carriers. The feeling is that rocket systems have been pushed to tasks that they have not been sufficiently qualified for, and an effort must be made to have really reliable vehicles going into operational use.

• The Scout vehicle (see page 30) is expected to place two experimental electrical propulsion units into orbit for testing by 1962. This decision advances the date estimated for an evaluation of electrical engines in the space environment (see January *Astronautics*,



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page 30), but does not surprise in view of the well-directed effort in this area.

• NASA will begin to move out of the study phase of large solid rockets into some major development work. In this connection, United Technology Corp. reported the third straight successful firing of its demonstration segmented conical solid rocket, and said that it will produce and test "huge versions of the solid-propellant device in the very near future."

• After an extended delay, the joint Nuclear Propulsion Office of NASA and the AEC issued invitations to companies for first-phase development of the Rover nuclear rocket engine. Selections will be based on a company's total capability to develop a nuclear rocket engine, although the initial phase will be confined to certain development tasks on nonnuclear engine components and assistance to the Los Alamos Scientific Laboratory for the Kiwi-B program. Deadline for submissions is April 3, 1961.

• NASA announced it will negotiate a $2,250,000 contract with one of four companies to manufacture 42 outer tanks for the Saturn booster. The companies are Boeing, Chance Vought, The Martin Co., and Chrysler Corp. Eight 70-in. tanks will be supplied for each of five Redstones, plus two spares.

• In another area relating to Saturn, NASA announced study contracts for Ryan Aeronautical ($145,828) and North American Aviation ($170,000) for studies of a "paraglider" technique for recovering the Saturn boosters. This involves a lightweight flexible wing which can be folded along the tank section and then deployed after motor burnout to glide the 50-ton casing to a ground landing. The system would involve controls and guidance.

• A threefold increase in the specific impulse of nuclear rockets is the goal of one line of NASA research. It has for some time weighed the idea of a rocket reactor in which the reactant mass would be heated by direct contact with gaseous uranium in a cavity. This would permit much greater operating temperatures and, hence, a specific impulse of about 2500. The major problem remains keeping the uranium gas from being ejected along with the reactant. (See Frank Rom's article in the October 1959 *Astronautics*, page 20.)

• NASA is studying three possible schemes for steering very large solid-propellant rockets. One method involves the injection of gases or liquids into the nozzle exit cone. A second technique involves four independent rotating solid rockets manipulated by the guidance system. The third uses a single solid-propellant gas generator exhausting through a complex valving system to fixed nozzles to control direction and roll. General Motors is studying the rotating solid rockets ($199,000) and Vickers Inc. is working on the gas-generator approach ($127,159).

• The ramjet program is beginning to show signs of activity, and the word is that toward the end of the year the ramjet will have regained some stature for advanced missions. Recently, representatives from Air Force Headquarters, WADD, Edwards AFB, BMD, and major aircraft companies reviewed Marquardt's propulsion program in a classified briefing at Van Nuys and witnessed tests at the company's research laboratory at Saugus.

SATELLITES AND PROBES

• Communication satellites are really hot. More than 40 companies lined up for NASA's Project Relay bidding, when only 20 were expected.

• The space agency is calling for an 85-lb satellite to be launched by 1962 with a Thor-Delta, with sufficient bandwidth to relay a television signal between the eastern U.S. and Europe. It would be placed in an elliptical orbit with an apogee ranging from 2800 to 3400 mi, a perigee of 650 to 1600 mi, and a period of 2 hr. Deadline for proposals was set at the sixth of this month.

• The military observation satellite programs also began moving into dramatic stages. Although cloaked in security, the Samos program appears in a position to produce results, and major contracts reflected the effort on Midas. Aerojet-General received a $12 million contract from prime contractor Lockheed Missiles and Space Div. for additional development work on the satellite's infrared subsystem and to produce an undisclosed number of prototype units; and Baird-Atomic received a $2 million Lockheed subcontract to carry out a reliability testing program in connection with Midas.

• It was a long, hard struggle, but General Electric finally succeeded in winning a major systems contract. NASA awarded GE's Missile and Space Vehicle Dept. a contract to build the Nimbus advanced weather satellite and integrate its subsystems. NASA will negotiate a $4.5 million contract covering the first two Nimbus satellites, but observers estimated GE would garner more than $200 million in total space business in future Nimbus work. Losers in the competition were Republic, Grumman, RCA's Astro-Electronics Div., Bendix Systems, and Temco. The 650-lb Nimbus will be launched into a 600-mi polar orbit from Vandenberg AFB using the Thor-Agena B. First launching is scheduled for March 1962.

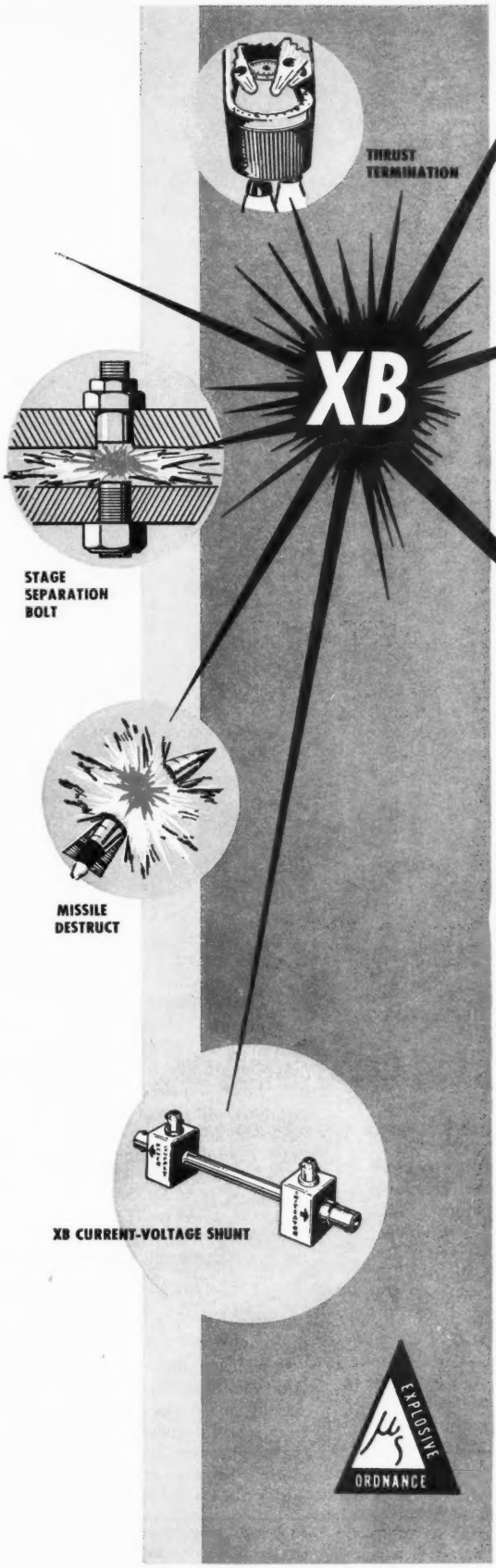
• Hughes Aircraft was chosen to build the Surveyor lunar soft-landing payload by NASA's Jet Propulsion Laboratory. Seven Surveyor payloads are to be sent to the moon in the 1963–66 period in a program to cost about $50 million, NASA said. The Hughes proposal calls for a 750-lb spacecraft measuring 11 ft in height and standing on three legs. It will be lowered to the moon at a speed of about 10 mph by a large solid-propellant and three vernier rockets. Equipment will include four TV cameras and a 60-in. drill capable of bringing up moon material for analysis by its instruments.

• In mid-Feb., NASA's second Scout scheduled for a try at orbiting the Langley 12-ft polka-dot sphere satellite for air-density studies came through. The first effort failed in December when a Scout second stage did not ignite.

• Besides the air-density experiment, Scout is slated to orbit a 163-lb micrometeorite satellite with an array of 160 pressurized cylinders to detect penetrations and a top-side sounding satellite to probe the ionosphere on six frequencies between 2 and 15 mc.

• Also, two United Kingdom Scout launchings are planned, the first of them involving direct ionosphere measurements. In addition, a Scout probe is planned to 6000 mi. The 100-lb payload would perform direct ionosphere measurements as well as propagate radio signals for ground analysis.

• Major scientific launchings with the Thor-Delta include a 400-lb atmospheric structures satellite to be placed in a near-earth orbit and an "energetic-particles" satellite to be placed in a highly elliptical orbit



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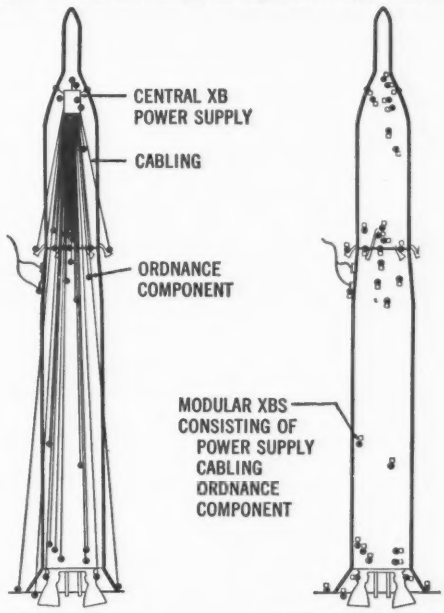
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with an apogee of about 40,000 mi. Latter will have 10 different particle detection systems, a magnetometer, and an optical sensing system to determine attitude. The atmospheric-structures satellite will include mass spectrometers to measure molecules, hot-cathode pressure gauges to detect atmosphere down to about one-hundred trillionth of sea level, and two hot-cathode ionization gauges capable of measuring still more sensitively.

SPACE TECHNOLOGY

• The most significant debate on space matters in Washington and technical centers across the country involves orbital operations vs. direct shots in space missions to the moon. The outcome of this debate will determine the direction, emphasis, and size of the national space program beyond 1965. The edge goes to orbital rendezvous and ferry techniques, and a dramatic expansion of the official space effort over the next three years.

• Key study contracts for orbital rendezvous and launching operations have been awarded three companies by NASA's Marshall Space Flight Center. Lockheed Aircraft received a $100,000 award to design an automatic rendezvous system using Thor-Agena B and Atlas-Agena B vehicles in which both the "target" and "chaser" have active guidance, but only the latter has propulsion capability to execute the joining maneuver. Douglas Aircraft and Chance Vought Aircraft received $92,000 and $105,000 study contracts, respectively, to perform six-month studies of the feasibility of launching space vehicles directly from earth orbit.

• The results of these studies could play an important role in determining the extent to which NASA can rely upon Saturn and orbital-rendezvous techniques for extensive space explorations, including manned landings on the moon.

• Under Air Force contract, Westinghouse Electric has developed a 150-watt thermoelectric generator using the solid radioactive isotope, Curium 242, as the heat source. The 40-lb generator, designated NAP-100, will be able to operate continuously for a year, the AF said.

• NASA, meantime, disclosed a requirement for a new Curium 242 generator of 15-watt output for lunar-landing missions. It prefers the Curium isotope because it is a solid. The Polonium 210 used in Martin's Snap III is a gas and has a shorter half-life. Furthermore, Snap III's power output is about one-third of NASA's requirement.

• For the AF's Dynasoar I suborbital hypersonic glider, NASA is studying a landing skid system employing wire brush material for the main skids and a metal-ceramic mixture (cermet) for the nose skid. The materials must have sufficient friction to stop the landing Dynasoar within 8000 ft.

• NASA studies of erectable structures have shown that a torus to provide living quarters for a manned spacecraft can be easily packaged in 8% of its inflated volume. NASA-Langley is continuing work with 10- and 30-ft models and is developing three-ply fabrics of neoprene or butyl rubber elastomers combined with nylon or dacron cord reinforcement. The space fabrics have demonstrated a 30-day survival capability in space environments, NASA said.

• Dynasoar contract awards went to Minneapolis-Honeywell Regulator for flight-control electronics and to Chance Vought for a ceramic nose cap for the vehicle proper . . . NASA will use Aerobees to launch 250-lb payloads carrying equipment to study the behavior of liquid hydrogen under zero G; lH_2 performance in valves will be part of the investigation . . . Aeronutronic will investigate semi-rigid and nonrigid space structures for the AF's WADD; Aeronutronic is the major contractor to the AF for Blue Scout . . . The Office of Naval Research has had some success in its program for developing hot-air balloons, being conducted by Raven Industries of Sioux Falls, S.D. One balloon was recently piloted to an altitude of 9000 ft in a 2-hr hop . . . Studies at NASA's Marshall SFC suggest that the polar properties of lubricants may hold the answer to many serious lubrication problems in missile and space systems. Polar synthetics such as di-2-ethylhexyl sebacate seem to adhere to metal surfaces more tenaciously than do petroleum products under low pressures.

MISSILES

• With less than a month in office, the New Frontier found itself in the middle of a flaming controversy over the "missile gap." At a top-level Pentagon background briefing reporters were advised that there is no significant disparity between the U.S. and Russia in ICBM weapons at the present time. Though Russia might draw ahead in ICBMs in the future, it was suggested, the U.S. would still have a sufficient strategic edge in manned bombers and submarine-launched missiles to forestall any "destruction gap."

• The position was so close to the one held by President Eisenhower during his last year in office that the newsmen reported that JFK agreed with Ike's appraisal. The political roof caved in on Kennedy, with delighted Republicans demanding that the new President apologize to Eisenhower and jeering that the New Frontier had managed to cancel the "gap" after 18 days in office. At Kennedy's order, White House Press Secretary Pierre Salinger repudiated the "backgrounders" coming out of the Pentagon, noting that the studies to which they referred have not yet been completed and that therefore they must be "inaccurate."

• The Administration's formal answer to the question of the missile gap will be embodied in Pentagon Comptroller Charles P. Hitch's special study of strategic weapons. This is one of four areas in which Kennedy demanded major reappraisals by newly appointed civilian officials. The others covered U.S. commitments and limited war capability, U.S. military installations and weapons research and development. Group studying the R&D problem is headed by Defense Research Director Herbert York.

• AF succeeded last month in orbiting its first Samos observation satellite aboard an Atlas-Agena A fired from Point Arguello, Calif. The 4100-lb object was placed in a 95-min orbit at altitudes ranging from 300 to 350 mi. It had no reentry capability like that planned for later Samos reconnaissance satellites, but it was presumably capable of television readout of its data to interrogation stations at Donnelly Flats, Alaska, and New Boston, N.H.

• In a remarkable first test shot, the AF successfully tested all three stages of its Minuteman solid-propellant ICBM, plus the Autonetics guidance system. The 4200-mi flight with 400 lb of range safety, test instrumentation and telemetry equipment proved that Minuteman should easily meet its flight objectives. Still a question was whether the Minuteman silos will be ready in time for operational missiles by mid-1962.

• Army Engineers returned construction bids for the first two

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flights of 20 Minuteman silos because they were about 150% above expectations. New bids were requested with relaxed schedules and penalty provisions, but with all the original silo construction requirements. Although the AF insisted that the first Minuteman silos will be ready on schedule, there was a growing conviction that the U.S. can build missiles faster than it can dig holes in the ground.

• The Army awarded contracts totaling $8,564,000 to Western Electric for further work on the Nike-Hercules missiles system: $4,000,000 for production engineering, to be done at Western Electric's Burlington, N.C., plant, the Bell Telephone Labs in Whippany, N.J., Douglas Aircraft in Santa Monica, and at White Sands Missile Range, N.M.; $3,064,000 for research and development of the improved Nike-Hercules, the major portion to be done at Bell Telephone Labs, and the remainder by GE-Syracuse and Western Electric-Burlington; and $1,500,000 for development of field manuals, to be done by Western Electric, Douglas, and GE.

RANGES AND TRACKING

• To remedy a gaping hole in the nation's "satellite fence" across the southern part of the country, the Navy is building a 560,000-watt transmitter at Archer City, Tex., 22 mi south of Wichita Falls. With more than 10 times the power of the two transmitters on either side, the Archer City installation will be able to bounce signals off passing satellites with sufficient power for the echoes to be picked up at all the existing receivers. The hole in the space surveillance net, called Spasur, was supposed to be filled by an Army Doploc radar system but this never met expectations.

• Philco field engineers will fill the spot of equipment specialist on the three-man NASA teams that will monitor Project Mercury flights in stations around the world. The teams, each made up of an NASA representative as communicator, a doctor, and the equipment specialist, will man all but the two main NASA stations.

• White Sands MTC renewed its contract with Land-Air for $6.5 million in data-collection and engineering services, and extended the company's coverage to Holloman's Aeromedical Field Lab, which is conducting deceleration tests and other human-factors work . . . The new vibration and acoustical analyzer developed for White Sands by ARGMA and Gulton Industries Ortholog Div. functioned accurately and reliably in its first test recently, delivering completely reduced data immediately after a missile firing . . . Army Ordnance issued a $2 million contract for routine data reduction at White Sands to Telecomputing Services Inc.

• Pacific Missiles Range, assigned operational control of worldwide Transit tracking last October, created a central Transit office last month, to be headed by Cmdr. James C. Quillin Jr., former deputy head of PMR Weapon Systems . . .

• The Bell Labs target-tracking radar for Nike-Zeus has swung into action on Ascension Island in the Pacific in tests preparatory to actual ballistic-missile intercepts. The Army is in the process of installing a complete Nike-Zeus system on Kwajalein.

R&D

• Dollars—9-1 million of them—flowed into research and development from the Federal Government in FY 1961. This estimate by the National Science Foundation compares with $8.6 billion in 1960 and $7.4 billion in 1959. Of the '61 funds, $850 million went for "basic research," of which a goodly portion might better be called applied physics.

The NSF figures for 1959 put Federally financed industrial research and development at $5.4 billion, and industry-financed work at about $4 billion. Of the $9.4-billion total for industrial research and development, only $344 million went to industrial basic research in 1959.

• Counterpointing the many recent successful launchings of developmental missiles and space systems have been several important advances in the communications and computing fields.

• Two came from Bell Telephone Labs. There, A. Javan and his colleagues produced, at first crack, a continuously operating gaseous optical maser that runs off a low-power source and can produce very pure light in any of 30 frequencies in the near infrared. A Bell team also demonstrated the feasibility of superconducting solenoid magnets producing very high fields. With a niobium-tin magnet material, it appears from their initial work that fields of 100,000 gauss can be built and sustained, carrying currents of 100,000 amp/sq cm of cross section.

• The gaseous optical maser, cheap and simple, can easily be set up for studies in a laboratory, and should greatly spur the space application of lasers, as well as prompt serious work on light for commercial communication channels.

• Superconducting magnets could prove a master stroke in fusion experiments, greatly extend the capabilities of traveling wave tubes and masers in satellite communication systems, and be a boon to the experimental physicist in many areas of work.

• An electronic switch with an action time of a billionth of a second was the contribution of Raytheon's Semiconductor Div. to the month's news. The switch incorporates Raytheon's avalanche-mode silicon transistor in a microwave strip transmission line, the first time this has been done, according to the company. The switch has a peak output of 50 w at 50 kc.

• ONR's Information Systems Branch announced that NYU scientists H. Kallman and J. Rennert, working with its support, have demonstrated in their laboratory a technique that permits information to be carried by light to a phosphor plate having persistent internal polarization, stored there for long periods of time, and then released in a fraction of a microsec by a scanning beam. The memory will give a useable signal from impressed data a number of times. It has no complicated circuitry and operates at room temperature. This area of work holds great promise for improving certain computer memories.

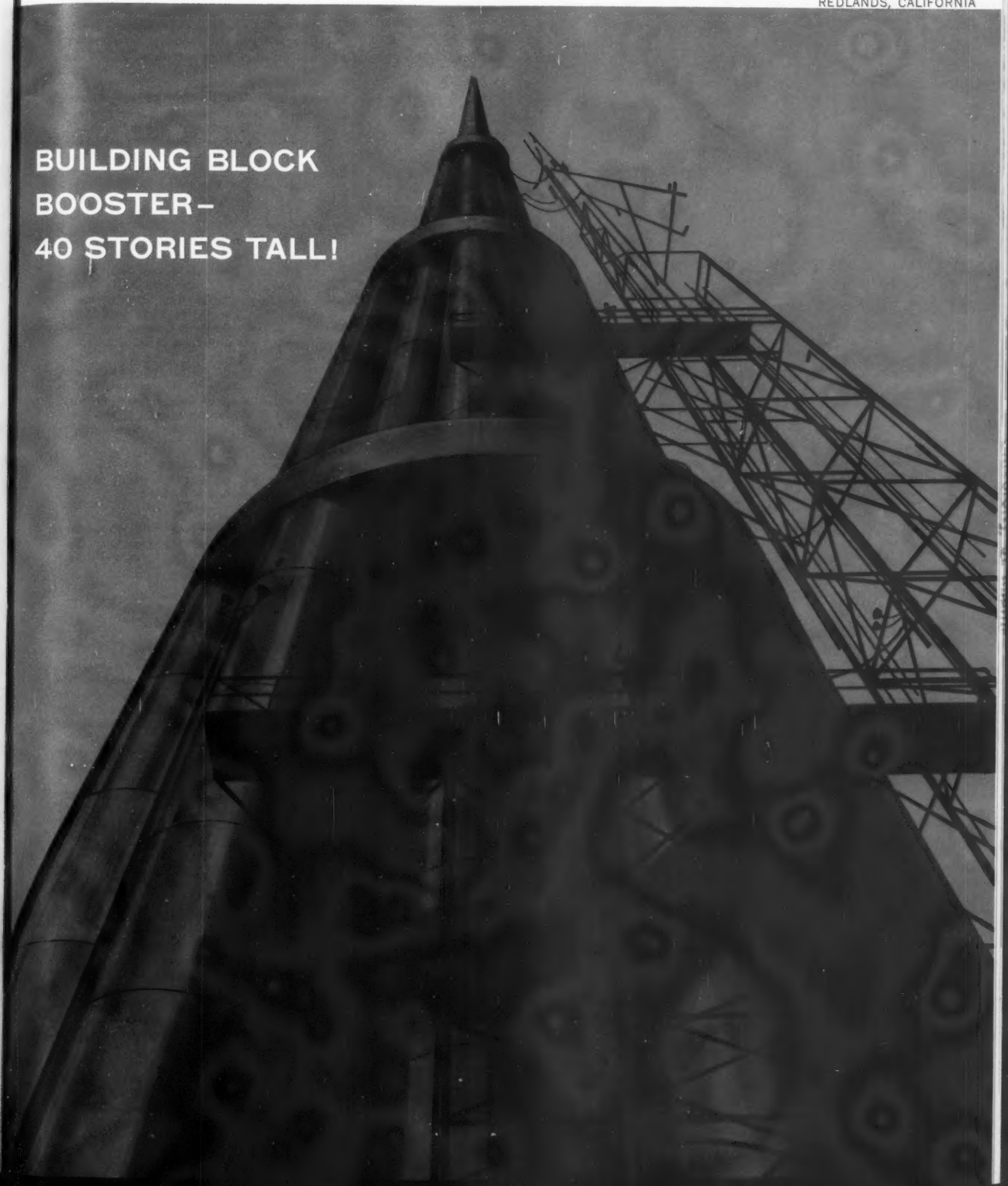
• A new Arthur D. Little program, designed for high-speed digital computers, performs a complete stress and deflection analysis for any thin elastic shell or rotationally symmetrical form subjected to arbitrary loading or temperature distribution.

PATENT POLICY

• Orders for the *Federal Bar Journal* issue dealing with the question of government contract and patent policy should be placed by the end of this month with FBA Headquarters, 1737 H. St., N.W., Washington 6, D.C. The price is $1.50 per copy. The printing covers only members and advance orders. ♦♦

This gigantic GCR-proposed solid propellant booster is made up of easy-to-haul segments that simply would be bolted together at launch site. It could put a 250,000-pound space station in orbit—or send a 60,000-pound manned spacecraft to the moon. It can be developed, built, tested, assembled, maintained, and operated for a small fraction of the cost of a comparable liquid system—yet it is much more reliable. It can be operational by 1967—if we start now. Smaller solid boosters—able to orbit 30,000 pounds—can be available by 1964. **GRAND CENTRAL ROCKET COMPANY**

REDLANDS, CALIFORNIA



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Mail bag

Wrong-Motor History

Dear Sir:

While reading the captions explaining the photographs at the bottom of page 28, "Simulated-altitude rocket testing" by B. H. Goethert, in the January *Astronautics*, I noticed a mistake which should be rectified.

The first large solid rocket tested at the Engine Test Facility at AEDC was Grand Central's Meteor. The second large rocket tested was the ABL X241. Both were developed for Vanguard, but were candidates for the USAF Thor-Able. The ABL X248 rocket was under development for Vanguard as a high-performance third stage. This rocket was tested at ETF, one month later, by the USAF for the Thor-Able vehicle, and was used as the third stage in the unsuccessful launching of August 1958.

The Grand Central Meteor is pictured in the photograph, not the ABL X248, and the chuffing sequence does pertain to that rocket. The ABL X241 and X248 never chuffed, but later tests of the X248 did show a phenomenon labeled as "outgassing."

The photograph of the frayed nozzle is that of the ABL X241 rocket which showed up in early tests. Early tests of the ABL X248 also revealed this problem, but the tunnel information was used to correct this.

ROBERT H. HEITKOTTER
Rocket Power Plant Research Engineer
Bureau of Naval Weapons
Washington 25, D.C.

Ed.: We appreciate this interesting history and the correction it makes. The caption was ours, not Dr. Goethert's, and our apologies to him.

Green Grow the Lilacs

Dear Sir:

In his article in the December 1960 *Astronautics*, Dr. Strughold makes the surprising remark that no such growth rate is known on earth as the 5 to 10 mile per day progess of the green areas on Mars.

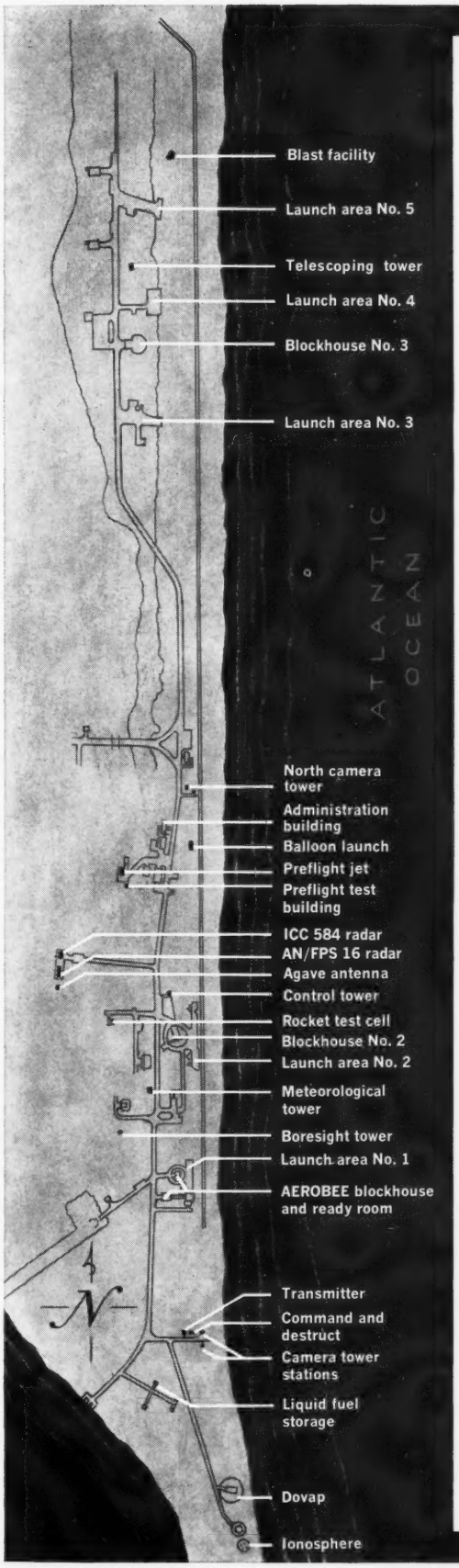
In fact (as can be quickly checked by simple arithmetic) an observer would see green areas growing at a rate of about 15 miles per day from Georgia to Canada during the months of March, April, and May.

ALAN H. STENNING
Professor, MIT
Nuclear Engineering Dept.
Cambridge, Mass.

More on Catapults

We were heartened to read Forrest E. Knecht's forthright opinions in the January *Astronautics*, p. 18, and would like to extend our congratulations on the revolutionary catapult design he reported. There is little point in carrying on an "En Garde Vous—Touche" contest, and so we would permit but one observation. Mr. Knecht has adequately expanded on the survey article in question but only in the direction of catapult-design techniques.

(CONTINUED ON PAGE 18)



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Wallops Space Flight Station is located on Virginia's historic Eastern Shore a scant 120 air miles from the Nation's Capital. Here on the beaches, where the famed wild ponies of Chincoteague run free, the mysteries of the cosmos are explored.

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tion and propulsion; in-space rescue, repair and refueling; space medicine and human engineering for crew survival; and re-entry and recovery systems to bring astronauts safely back to earth.

When men finally move out into space, Northrop equipment and techniques will make the task simpler and safer.

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For the record

The month's news in review

Jan. 1—Army releases details of Davy Crockett rocket which can be launched from a jeep.

Jan. 10—Polaris A-2 scores third straight success in 1600-mi flight down Atlantic missile range.

Jan. 11—U.S. announces plans to build anti-submarine warfare missile test range off Bahamas, dubbed AUTEC for Atlantic Underwater Test and Evaluation Center, at cost of about $100 million.

—President-elect Kennedy selects Jerome B. Wiesner of MIT to be Special Assistant to the President for Science and Technology.

Jan. 12—Italy launches its first successful high-altitude two-stage rocket to 105 mi over Mediterranean in joint Italy-NASA space research program.

Jan. 15—NASA and France's Commission for Space and Scientific Research discloses holding preliminary talks on a cooperative satellite program.

Jan. 16—Senate Astronautics and Space Sciences Committee votes inquiry into U.S. space achievements as compared with that of Soviet Union.

—ITT receives first allocation of radio frequencies to private industry from FCC for experiments in bouncing signals off the moon and artificial satellites.

Jan. 17—Joint Congressional Atomic Energy Subcommittee on Research scores Eisenhower's decision to curtail development work on atomic airplane.

Jan. 18—AF discloses that a 15-man scientific group has been engaged since October in an appraisal of what military space projects should be pursued and will issue its report on Feb. 15. Trevor Gardner, former assistant secretary of AF R&D, heads the unit.

Jan. 19—FCC okays AT&T plan to set up first satellite space communications link between the U.S. and Europe on an experimental basis.

Jan. 20—AF Titan shot fails when second stage doesn't ignite.

—Air Space Surveillance Control Center expects Discoverer XIX to burn up in atmosphere today.

Jan. 24—NASA awards ion-rocket study contract to United Aircraft Corp.'s research laboratories.

—Army Hawk intercepts Corporal missile in test.

Jan. 25—NASA awards spaceship-refueling study to Lockheed Aircraft.

—NASA reveals it has chosen 12 women airplane pilots to undergo tests to determine to what extent women may be used in spaceflight research.

Jan. 28—NASA announces formation of the Goddard Institute for Space Studies in New York City to begin operations in May. GISS will be an extension of the Theoretical Div. of Goddard Space Flight Center.

—France's Space Research Commission approves space plan calling for launching of more than 200 sounding rockets in next five years.

Jan. 30—Twelve European nations confer at Strasbourg, France, on plans for joint space venture.

Jan. 31—"Ham," a male chimpanzee, is rocketed 420 mi over Caribbean in Redstone-Mercury No. 2 capsule, and returned safely.

—AF sends Samos II reconnaissance satellite into polar orbit. ♦♦

Mail Bag

(CONTINUED FROM PAGE 14)

A few words regarding rocketry are also in order.

The whole intent of imparting a ground-supplied velocity to a rocket is simply to increase the rocket's payload (i.e., reduce the launch-vehicle's task). Orbital velocity cannot be feasibly imparted to a satellite at launch, hence the desire to impart as much velocity as is practical. A launch velocity of 1000 fps was selected in the survey article, but note that the theoretical payload increased only 11%, or about 1500 lb for a 1-million-lb missile (e.g., similar to the Saturn C-1).

Mr. Knecht prefers an end speed of 550 fps, which should increase the referenced payload by considerably less than 1000 lb. No matter how clever we design a catapult, the payload increase results only from the launch end-speed. Accordingly, the 10,000-lb payload increase brought about by the catapult design of Mr. Knecht is indeed a happy ending.

Further, it is not clear if Mr. Knecht intends to build this 1000-ft-long catapult vertically; however, we trust it to be so. For not only are there considerable losses incurred by a missile executing a near 90-deg pull-up, but also there are no doubt numerous range safety officers and other launch personnel who would not appreciate a Saturn C-1-type launch vehicle flying nearly horizontal at sea level.

There is a better plan which was not presented originally, namely, air-launching from a large aircraft. The latter technology will, incidentally, support the facts reported herein.

In conclusion, we do not agree with Mr. Knecht in fact or in principle. Happily, we all do share a common interest, namely, that catapult techniques may well boom on the moon.

J. W. DORSEY, Design Specialist, and
M. Stoiko, Asst. Tech Director
The Martin Co.
Baltimore 3, Md.

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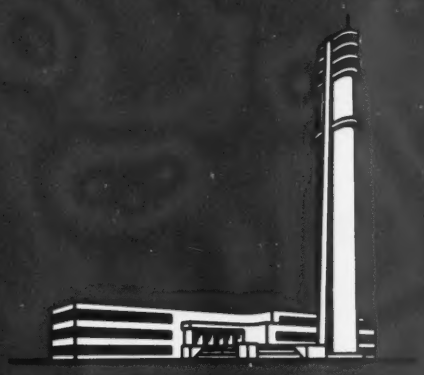

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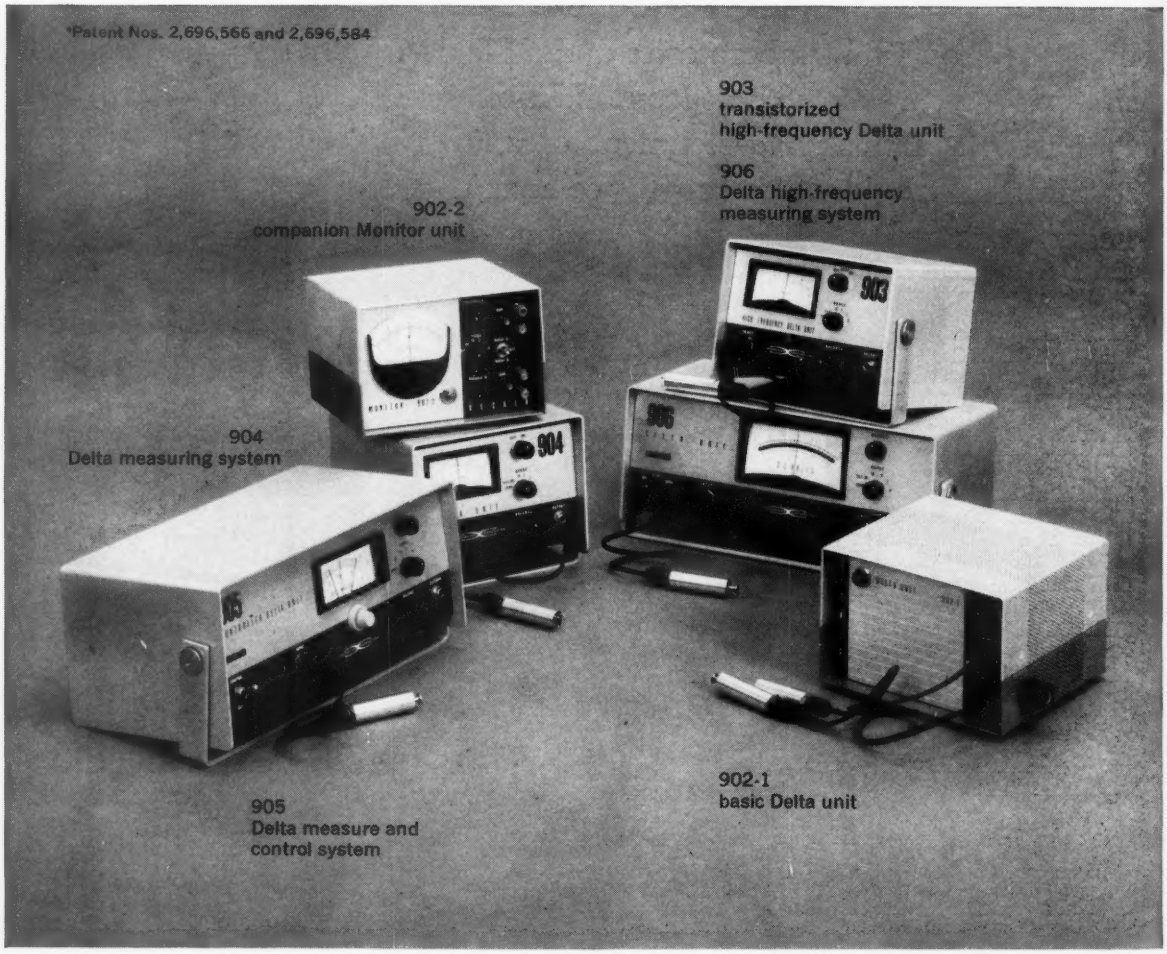

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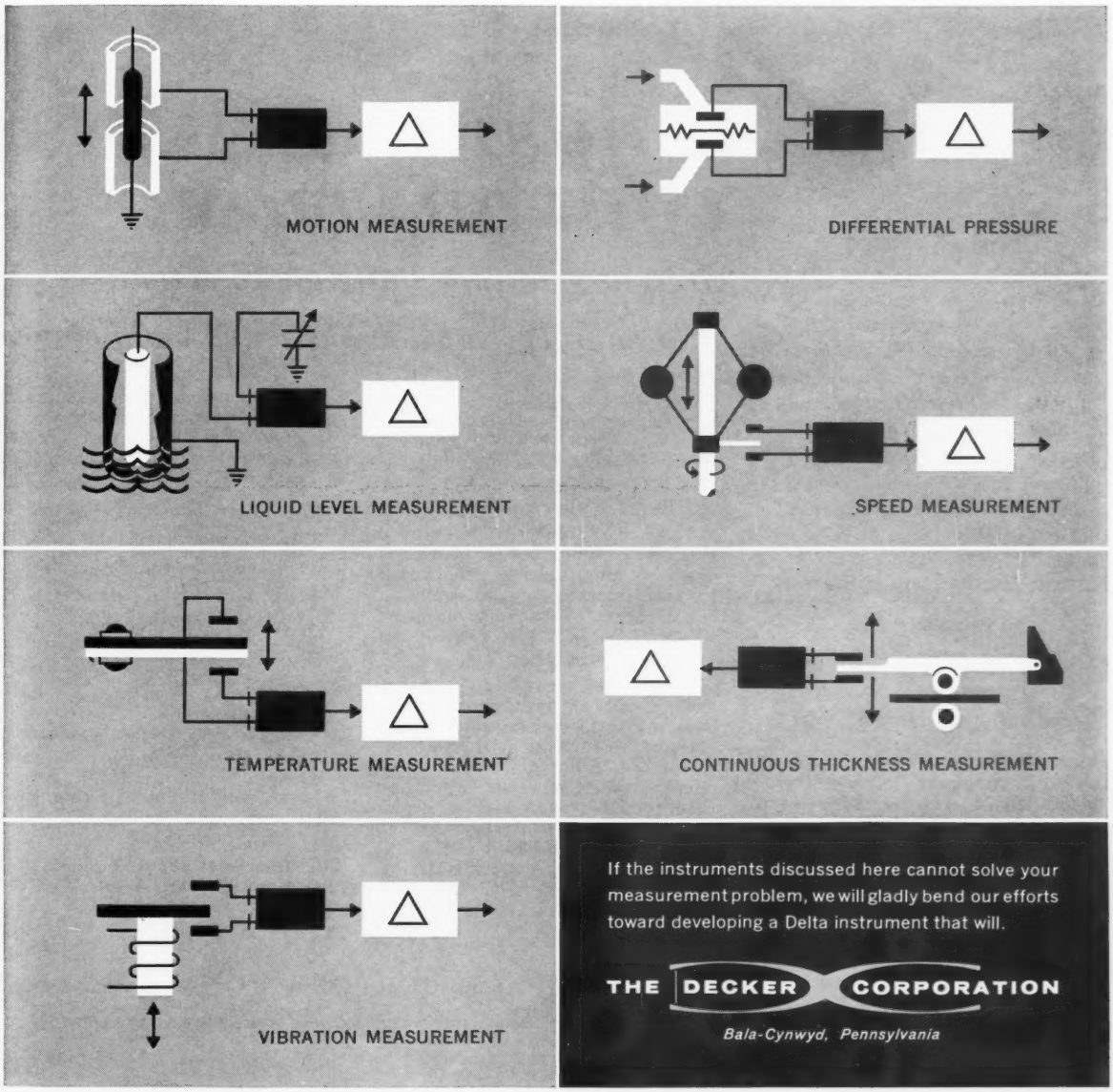
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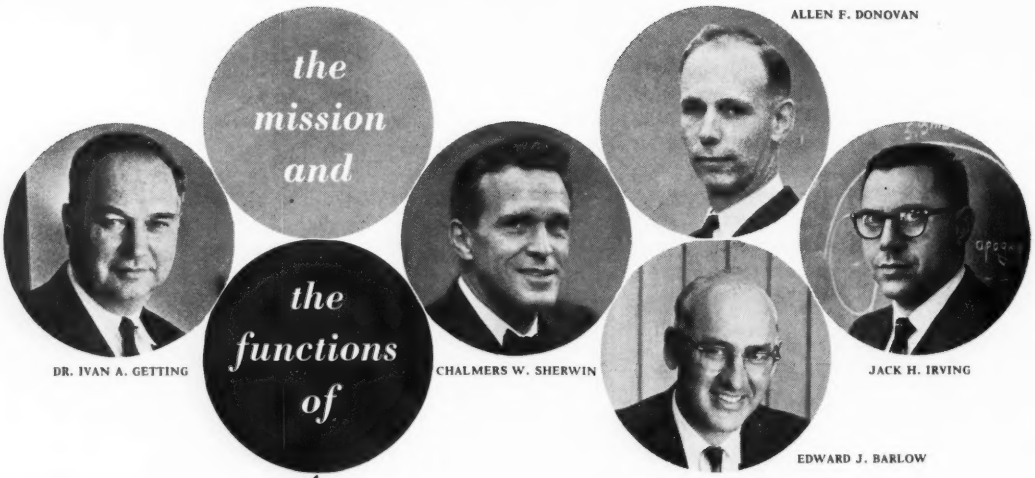

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What is the role of the AMERICAN ROCKET SOCIETY? The Society exists for one principal purpose—to furnish the machinery for communication within and between the many scientific disciplines essential to the success of space exploration. Only by the establishment of a synergistic environment for interchange of knowledge and ideas will we be able to transmute the varied technologies into workable space vehicles.

The machinery is established by our Board of Directors and standing committees and serves the membership through the operations of the technical committees. Appointments of committee chairmen and members have long since been completed and the objectives for 1961 established.

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- Top-quality papers for our publications and meetings
- Continuing improvements in our programs
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Stop briefly to reflect how fortunate you are to be living in this time and to be working in a profession so challenging. But don't reflect too long. There's too much left to do!

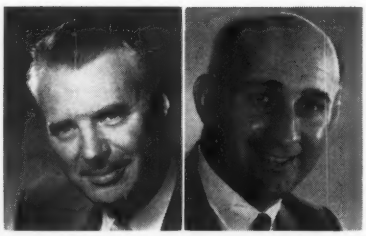
Harold W. Ritchey
President, AMERICAN ROCKET SOCIETY

F-1 engine development

Looming large in the U.S. space program, the tremendous F-1 engine has moved with surprising speed to the testing stage

By D. E. Aldrich and D. J. Sanchini

ROCKETDYNE DIV. OF NAA, CANOGA PARK, CALIF.



Aldrich Sanchini

David E. Aldrich, manager and chief engineer for the F-1 program, has had 13-year's experience in rocket-engine development. He joined Rocketdyne in 1951, serving for $2^1/_2$ years in advanced design and then, since 1954, as project engineer and program manager of new large-engine developments. Air Force programs with which he has been associated include Reap, the fluorine feasibilty program, and the F-1 engine program. His background includes a B.S. in mechanical engineering from the Univ. of Illinois in 1933, teaching engineering at Washington State Univ., and five years in the Army in World War II, the last $2^1/_2$ years as a member of the Anti-aircraft Artillery Board.

Dominick J. Sanchini, assistant engineer for the F-1 program, has been associated with Rocketdyne since 1953 as a research and project engineer. He has assisted in experiments involved in the testing of large rocket engines, has been responsible for program analyses for rocket engines and components, and was responsible for technical direction of an F-1 experimental engine program. His background includes a B.S. in mechanical engineering from Lehigh Univ. in 1951, a three-year tour of duty in the U.S. Navy, an LL.B. from the Univ. of Southern California in 1958, which led to his being admitted to the California State Bar in 1959, and $2^1/_2$ years as an engineer for Standard Oil of New Jersey before joining Rocketdyne.

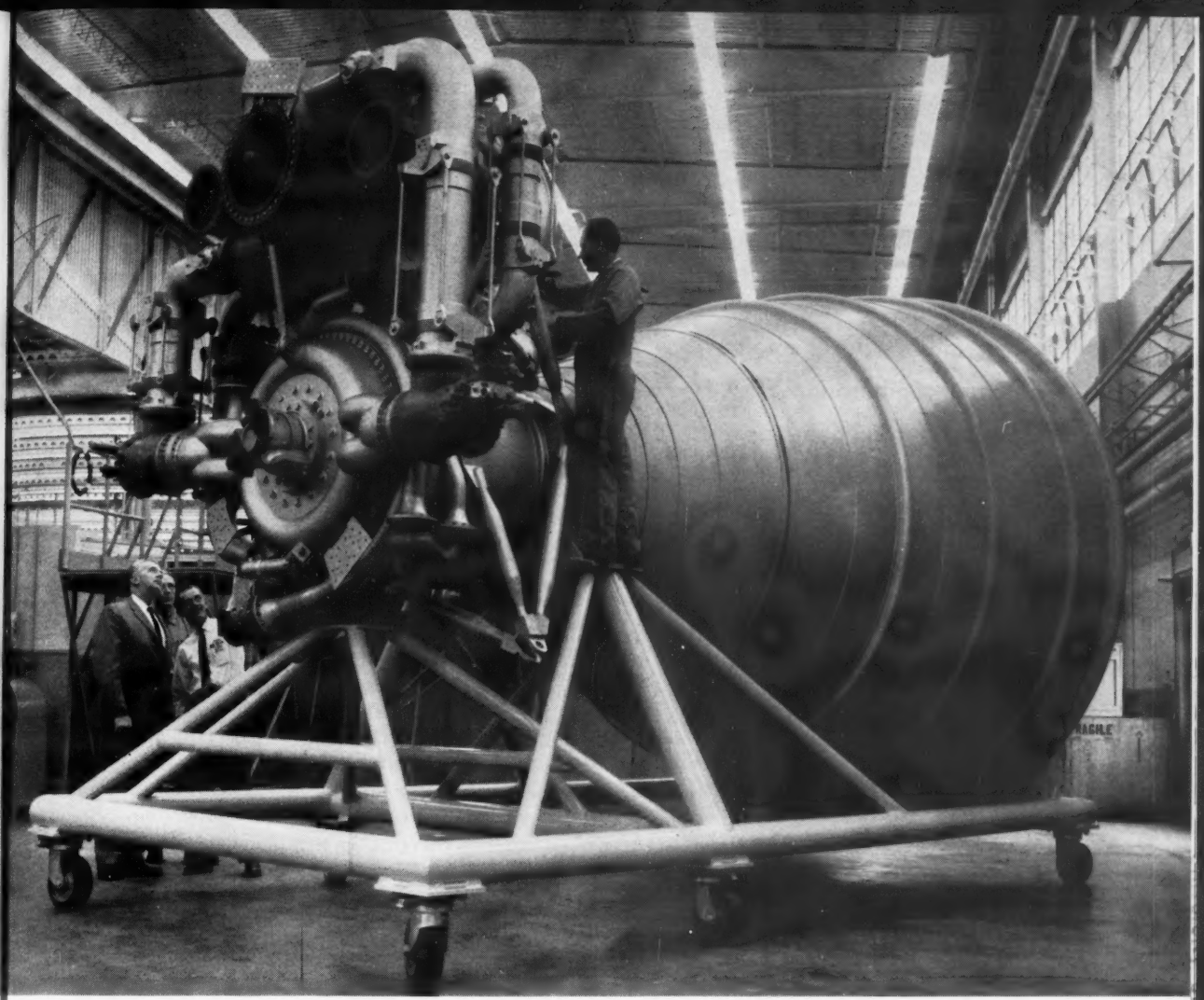
A COMPARISON of satellite weights announced by the Soviet Union with the weights of satellites launched by the United States demonstrates a significant difference in capabilities. The first two Soviet satellites weighed 184 and 1120 lb, respectively. Our first satellites weighed 31 and $3^1/_4$ lb, respectively. This gap in weightlifting capability has continued. For example, our first artificial planet, Explorer IV, weighed about 13 lb. The first Soviet artificial planet weighed about 3100 lb. Our Discoverer series of recovery vehicles weigh about 1700 lb. The recovery vehicles launched by the Soviet Union weighed about 10,000 lb.

Thus, it became obvious that we should "leapfrog" the next step in rocket-booster technology and begin immediately the development of very-high-thrust booster engines to accomplish the ambitious space programs of the near future. Manned orbital flight and instrumented probes to the moon and nearby planets are planned for the early 1960's. Relatively large manned earth-orbiting laboratories, manned space vehicles to the moon, and manned orbital trajectories to the nearby planets are planned for the late 1960's. The spacecraft accomplishing these later missions, the "wagon trains" of the space age, will be Nova-class vehicles, using clusters of F-1 engines, the subject of this discussion.

We can illustrate the capabilities of Nova-type vehicles powered with high-energy upper stages by discussing several typical missions which could be accomplished with the same booster. For purposes of illustration, assume the use of a booster with six F-1 engines clustered for a takeoff thrust of 9,000,000 lb.

A vehicle of this type would be capable of lofting up to 400,000 lb into a low-altitude orbit. For example, a mission could be to establish a manned laboratory for astronomical and earth observations, as well as other scientific and technical studies. Or large "space platforms" could be assembled in 400,000-lb increments by multiple-launch and rendezvous techniques. In addition, a large lunar vehicle, or vehicles for manned interplanetary flight, could be assembled and fueled while in a "parking" orbit. The use of the F-1 engine would considerably reduce the number of missions required to assemble very heavy, multiple-unit space platforms or large interplanetary vehicles.

Another typical vehicle would be capable of launching a 65-ton payload into a 24-hr orbit for such diverse functions as astronomical studies, weather observation, earth surveillance, navigational systems, and radio and television communications. Such capsules, capable of being repaired and maintained, could very well be an



A mockup of the F-1 engine suggests its enormous power, 1.5 million lb thrust with the conventional liquid propellants oxygen and kerosene (RP-1).

economical solution to the lofting of a variety of satellite systems.

A vehicle of this type would also be capable of placing up to 90,000 lb into a Mars orbit. With such a payload capability, a capsule could be well equipped with instrumentation and telemetering equipment. It could launch robot probes to the surface of the planet and relay the telemetered information back to earth stations. With the F-1 engine in the typical six-engine cluster and with high-energy upper stages, we would be capable of accomplishing a manned moon landing and return with an earth-landing weight of approximately 20,000 lb.

The Rocketdyne F-1 engine, being developed under NASA contract for a Nova-type vehicle, is the direct result of such planning.

Although the contract for the development of the F-1 engine was signed in January 1959, the development of a single-chamber 1,500,000 lb-thrust engine was already well started. Under the Air Force rocket engine advancement program, studies of the feasibility of rocket engines up to 1-million-lb thrust were begun as early as 1955. These culminated in 1957 with a detailed analysis of a single-chamber million-pound-thrust engine with supporting model testing and full-scale thrust-chamber design. Later in the year, the program was realigned to include three full-scale thrust-chamber firing attempts. These tests were concluded in March 1959 with a brief mainstage test at 1-million-lb thrust that demonstrated stable combustion.

F-1 Contract Backed by Studies

Thus, with this preliminary work, the hardware, the facilities, and other necessary capabilities were being developed at the time of the NASA contract award for the development (CONTINUED ON PAGE 46)

LR-115 oxygen-hydrogen engine

The first major rocket engine to make use of the classic propellant combination of O_2-H_2 has moved into the final stages of development, preparatory to actual flight test

By Richard C. Mulready

PRATT & WHITNEY AIRCRAFT, DIV. OF UNITED AIRCRAFT CORP., WEST PALM BEACH, FLA.

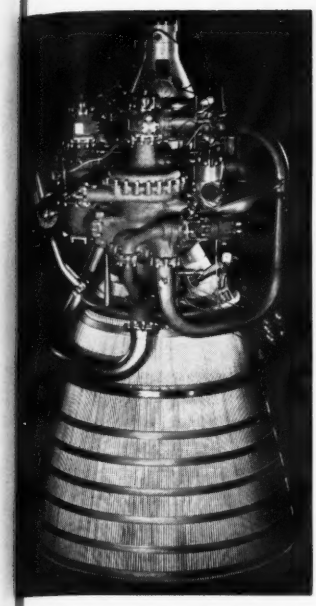
THE LR-115 rocket engine under development at Pratt & Whitney Aircraft is designed specifically for application in the upper stages of space vehicles. The hydrogen and oxygen propellants employed in this engine, in combination with a high nozzle-expansion ratio and a more efficient turbopump cycle, produce a specific impulse which is 35% higher than lox-kerosene engines. Moreover the liquid-hydrogen fuel permitted design approaches which resulted in major simplification over conventional gas-generator turbopump systems. The LR-115 engine is used in pairs on the Centaur space vehicle, and the LR-119, a later version, will power the upper stages of Saturn.

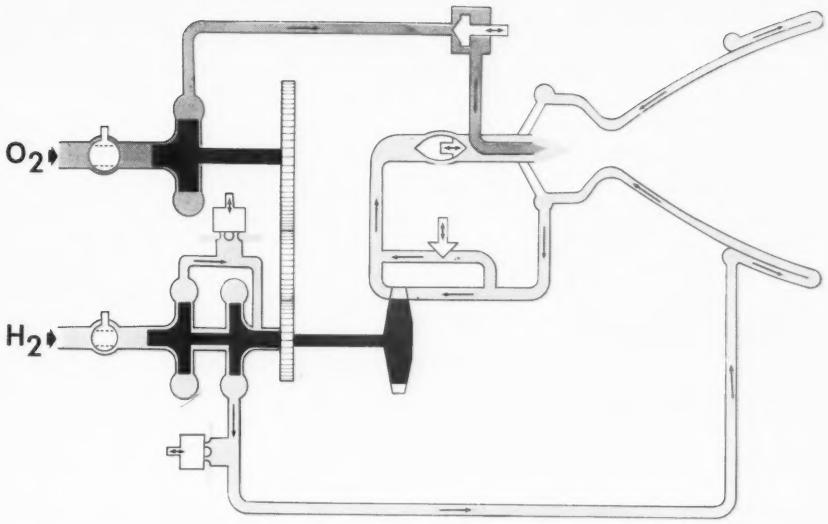
Shown at the top of the following page, the LR-115 engine is rated under space conditions at 15,000 lb thrust and has a nominal specific impulse of 420 sec. The engine operates at a nominal chamber pressure of 300 psia with a nozzle expansion ratio of 40. A regenerative turbopump cycle, which starts on vehicle tank pressure, and a high-energy electrical-ignition system provide the capability of multiple restarts in space. The complete engine assembly is gimballed to permit thrust-vector control.

A simplified schematic of the engine propellant-flow system appears on the next page. It can be seen that the hydrogen fuel, after passing through the two-stage centrifugal pump and the thrust-chamber cooling jacket, is expanded in a turbine before being injected into the combustion chamber. Because of the unique physical properties of liquid hydrogen (that is, low critical temperature and pressure, high specific heat, low initial temperature), the heat rejected to the fuel in the thrust-chamber cooling jacket provides sufficient energy to drive the turbopump with turbine-inlet temperature of less than 400 Rankine. In addition to eliminating the need for a gas generator, with its attendant control complication and exhaust-products disposal problem, there is also a performance advantage with this cycle, in that all propellants are burned under maximum impulse conditions in the main chamber.

At thrust-chamber metal temperatures as low as 150 Rankine, the energy available in the initial propellant flow induced by the vehicle supply system is sufficient to begin the turbopump acceleration. Coincident with the start of turbopump rotation, the initial propellant flows ignite in the thrust chamber, and the engine accelerates to rated conditions. No additional source of starting energy is required. The overboard valves shown at the interstage and exit of

Richard C. Mulready is chief of advanced technology at Pratt & Whitney Aircraft's Florida Research and Development Center. After graduating from MIT in 1946 with a degree in aeronautical engineering, he joined the Research Dept. of United Aircraft Corp., and in 1952 transferred to Pratt & Whitney as an assistant project engineer assigned to various engine development programs. Since 1956, he has worked on advanced engine development employing liquid hydrogen, and was project engineer in charge of development of the LR-115 engine until recently promoted to his present position.



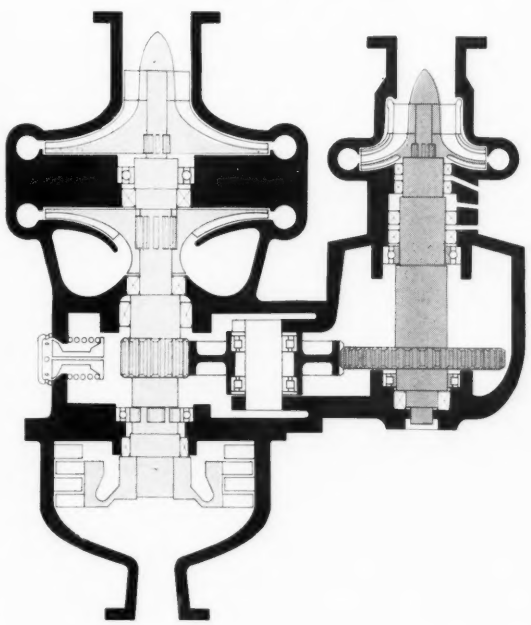


LR-115 Engine and Propellant-Flow Schematic

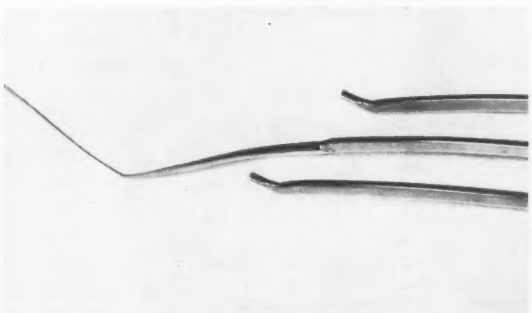
the fuel pump permit purging the vehicle propellant supply system and precooling the engine pump prior to start. The oxygen pump is gear-driven from the turbine shaft, and its output passes through a throttling valve used to make the factory setting of mixture ratio during engine acceptance testing. The line and valve shown bypassing the turbine represent the thrust control which modulates the turbopump output to maintain the desired chamber pressure.

The engine is designed to provide a capability of multiple restarts in space with coast periods of many hours between firings. The problems associated with maintaining a conventional lubrication system under the conditions which will exist during the coast phase made it desirable to eliminate oil lubrication in the gearbox. The gears and the bearings in the turbopump, shown in section in the illustration below left, have been developed to operate dry with hydro- (CONTINUED ON PAGE 85)

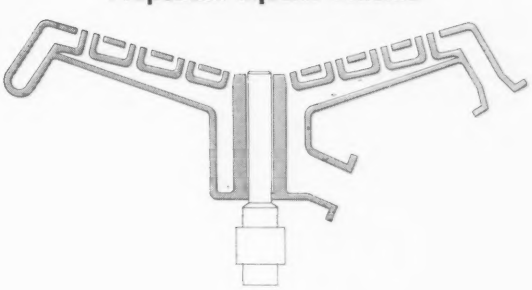
Turbopump Cross Section

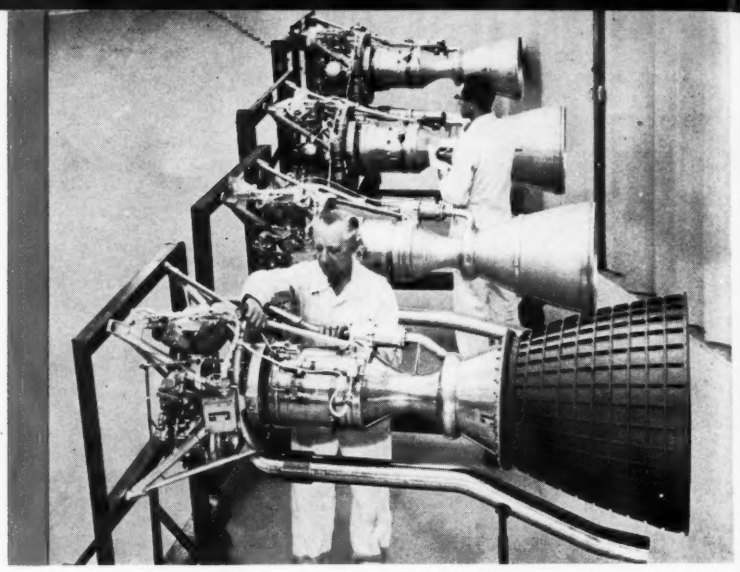


Thrust-Chamber Tubing Details



Propellant Injector Scheme





The Agena engine

Evolved over the past three years, the Agena system, featuring storable propellants and restart capability, has exhibited a flight reliability second to none

By David Feld

BELL AEROSYSTEMS CO., BUFFALO, N. Y.

David Feld is technical director for all of Bell Aerosystems Agena engine programs. A graduate of City College of New York, with a B.S. in mechanical engineering, he joined Bell in 1946, and did design work on liquid-rocket components. In 1948 he joined the staff of Martin Co., and worked on propulsion-system developments, flight-testing procedures, and coordination of flight-test programs. Then, rejoining Bell in 1950, he directed ground firings of various developmental propulsion systems and missiles, and later, as a systems engineer, supervised a group of designers and followed developments through the production-testing phase.

FOUR models of the Bell Agena engine, shown above, back to front, as they emerged, have been developed to meet the varying requirements of the Lockheed Missiles and Space Div. satellite programs. Modifications have included increased thrust-chamber area ratio, gimballing capability, change of propellant combination, addition of pump inducers, simplified control system, addition of restart capability, addition of power takeoff for hydraulic power, and demonstration of storage capability in the drained and unflushed condition. All of these changes have been accomplished within a span of three years while demonstrating flight reliability second to none. The exceptional performance achieved to date is a tribute to a design philosophy which allowed significant advances in the state of the art, yet retained the basic design features of the major components and the demonstrated reliability of previous models.

The engine to be discussed here is the latest version of Agena, the Model 8096, officially designated the XLR81-BA-9 Rocket Engine. It is the front engine shown in the photo here.

The Model 8096 is a pump-fed bipropellant engine capable of two starts at altitude. It has thrust-chamber gimballing ± 5 deg in a square pattern. The gimballing system is powered by a fuel-driven hydraulic motor pump bled from a separate port on the fuel-pump housing. The engine envelope is a cylinder 83 in. long and 35.5 in. in diam, with four symmetrical attachment points on the 35.5-in. diam. Both propellant-pump shaft seals are replaceable in the field within 8 hr. Individual calibration of the turbine pump and thrust chamber is of sufficient accuracy to allow field replacement with the same confidence factor of predicting flight performance as existed on the original engine.

A schematic of Model 8096 appears on the opposite page.

A typical start sequence goes as follows:

1. DC firing signal is applied simultaneously to one igniter assembly and the solenoid in the gas-generator valve.

2. The solid-propellant grain of the gas generator ignites and accelerates the turbine wheel.

3. When sufficient actuating pressure is generated by the fuel pump, the gas-generator propellant valve opens, allowing the turbine to "bootstrap" itself to operating speed.

4. The spring-loaded oxidizer valve is actuated by oxidizer-pump discharge pressure.

5. A manifold pressure switch is employed to detect oxidizer flow; actuation of this switch completes an electrical circuit to the fuel-valve solenoid, and thus opens the thrust-chamber fuel valve, completing the starting cycle.

The shutdown cycle is effected by a DC signal to the oxidizer-valve fast shutdown system, and a loss of power to the fuel-valve and gas-generator-valve solenoids. A restart is accomplished in the same manner by energizing the igniter in a second starter can. For ground operation, safety circuits are employed to initiate an automatic shutdown in the event of overspeed, decay in chamber pressure, or a delayed start. For maximum reliability, all safety circuits except the thrust-chamber pressure switch are removable for flight.

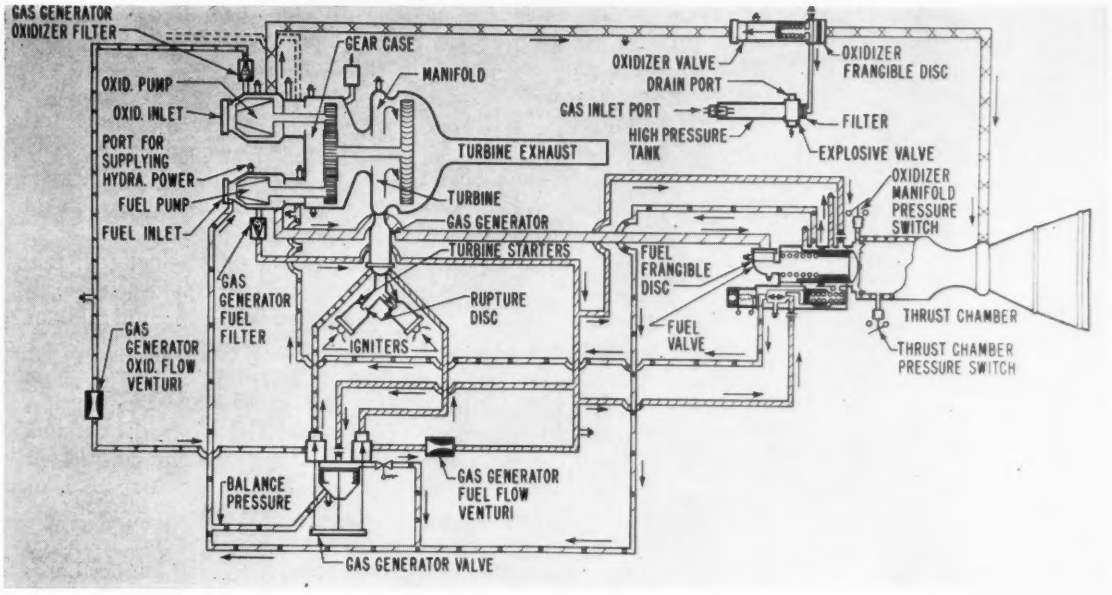
As to major components, the thrust chamber is all-aluminum construction and is regeneratively cooled by the oxidizer to the limits of the heat sink available. Coolant passages are formed in the aluminum chamber wall and nozzle by a Bell Aerosystems-developed gun-drilling technique. The divergent portion of the nozzle is a radiation-cooled titanium extension, supported by molybdenum hoops and stringers on the outside. The inside is coated with aluminum oxide as a thermal barrier.

Critical design areas encountered during the development of this thrust chamber centered on combustion efficiency—heat-flux tradeoff and nozzle-extension development. To obtain the required performance of approximately 98% combustion efficiency, while simultaneously holding the heat rejection to the thrust-chamber walls within tolerable limits, it was necessary to utilize high-velocity flow in the oxidizer coolant passages and careful injector design for peripheral film cooling.

One Propellant for Cooling

The combination of large area ratio and high-performance injector made it impossible to cool the entire chamber by forced convection using only one propellant. Alternative approaches were therefore taken, one using fuel to cool the divergent portion of the chamber, and the other a radiation-cooled nozzle extension. The complexities associated with the fuel-cooled nozzle extension—weight, auto-ignition on shutdown, and additional potential leak points—made it unappealing, and most effort went into the uncooled extension. By the use of titanium, satisfactory radiation cooling at altitude has been accomplished while retaining the ruggedness required for field installation. (CONTINUED ON PAGE 68)

Propellant-Flow Schematic for Agena Model 8096



Scout propulsion

The swift and sure development of this four-stage space vehicle, which qualified for an orbital mission in its first two flight tests, demonstrates a new maturity of the solid-rocket industry

By R. D. Smith and J. G. Thibodaux Jr.

NASA LANGLEY RESEARCH CENTER, LANGLEY FIELD, VA.

Smith Thibodaux Jr.

R. Donald Smith graduated from the College of William and Mary with a B.S. in chemistry in June 1955, and joined Langley a year later. Since that time, he has been concerned with many projects in rocketry, notably as engineer in charge of the Langley propellant-processing facility, propulsion engineer on the Little Joe vehicle, and propulsion monitor for the second stage of the Scout vehicle.

J. G. Thibodaux Jr., head of the NASA-Langley Applied Materials and Physics Div., has been responsible for all propulsion for Langley-sponsored rocket research vehicles launched since 1946. These number over 5000, and include single and multiple clusters of rockets arranged in as many as six stages—for example, the Scout, Little Joe, Journeyman, Javelin, and Shotput vehicles. A chemical engineer, graduated from Louisiana State Univ. in 1942, his many engineering contributions to the U.S. missile and space programs include the invention of a novel spherical rocket motor and techniques for producing it.

IN THE spring of 1958, the NACA began a modest study of a simple, relatively inexpensive, general-purpose vehicle to research the problems likely to be encountered in man's conquest of cislunar space. The initial guide lines of this study involved three principal missions. The first was to provide a vehicle capable of putting payloads of up to 150 lb in an orbit having a perigee of 300 mi. The second was to give the same vehicle a capability of launching vertical probes to and beyond one earth's radius with payloads up to 200 lb. The third was to use the same vehicle for studying re-entry problems at orbital and superorbital velocities. With the impending consolidation of the NACA into NASA, the study was accelerated, and in October 1958 the study became an official funded NASA program designated "Scout." At this time, most of the concepts to be employed in the vehicle's design had been formulated, and detailed specifications for the vehicle were completed. Chance Vought Aircraft was selected as the prime contractor, and systems management was assumed by the NASA Langley Research Center, which had conceived the Scout project.

Propulsion of the vehicle was the first major problem requiring a solution. It is the purpose of this article to discuss some of the philosophy used in arriving at a suitable propulsion system, to review some of the highlights in development of this system, and to report on preliminary results of the propulsion-system's performance obtained from two successful vehicle launchings.

A review of all solid-propellant rockets under development at the time the Scout was envisioned revealed that the largest solid unit that had been successfully static-tested was Aerojet-General's Jupiter Senior. It was felt that this program, originally sponsored by the Navy and subsequently discontinued, could be revived to furnish a suitable first-stage motor with a minimum of additional development costs. On this basis, performance studies were made with various combinations of other existing units and with a number of hypothetical rockets which could be easily developed within the framework of existing rocket technology. These studies indicated that a four-stage vehicle would be required.

Thiokol-Redstone had successfully fired an XM-20 rocket loaded with a new, high-performance PBAA propellant. It was evident that this unit could serve as a suitable second stage. In the closing days of the Vanguard program, the Allegany Ballistics Labora-

tory (ABL) developed the X-248 motor, and this unit was chosen as a fourth stage.

All that remained was to develop specifications for an entirely new third stage which was properly sized to give a nearly optimum staging ratio and which would utilize the most advanced design techniques embodied in the other units. Detailed calculations, and discussions with the Allegany Ballistics Laboratory, led to the X-254 motor, which is essentially a scaled-up X-248.

The Scout makeup is shown below. All four of the propulsion units are basically simple rockets and do not employ sophisticated hardware for thrust vector control or thrust termination. The first two stages use metal cases and fixed all-metal nozzles with graphite inserts. The two upper stages utilize glass-fiber and plastic cases and fixed glass-fiber and plastic nozzles with graphite inserts.

The first stage is guided with simple jet vanes and aerodynamic fin-tip controls actuated by a hydromechanical servosystem. Second- and third-stage guidance and control are furnished by auxiliary hydrogen-peroxide monopropellant rockets with electrically actuated valving systems. The fourth stage is stabilized by rotation about its own axis. This rotation is accomplished with small solid-propellant rockets identical to those used in Vanguard and a spin table identical in design to that used by Thor-Delta.

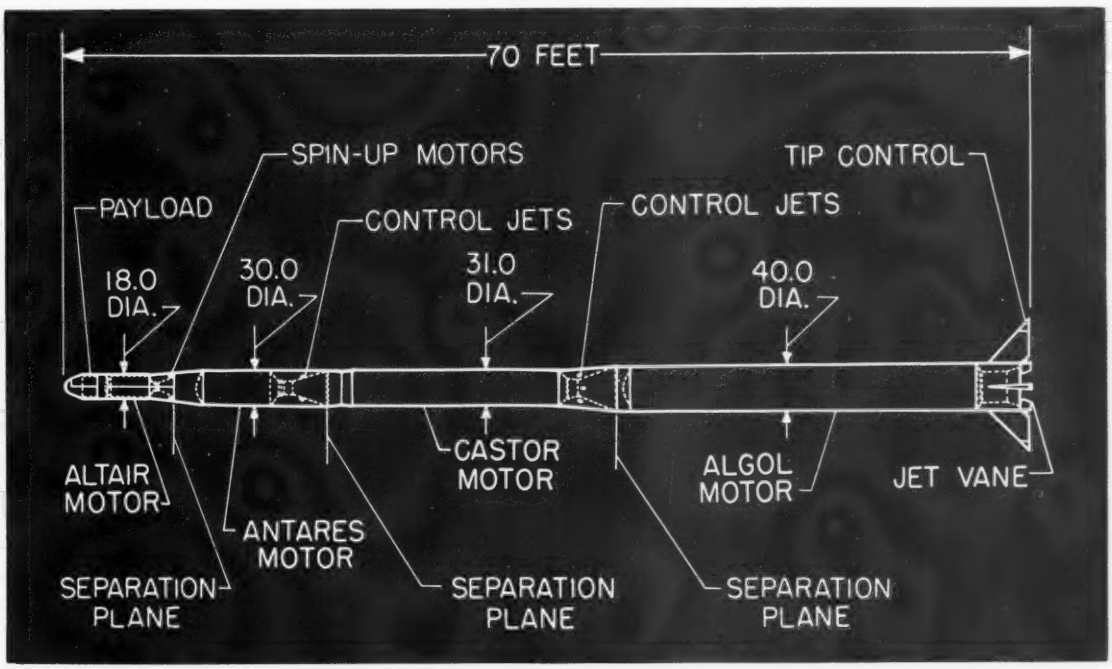
The rocket cases provide the primary structure for carrying the aerodynamic and inertia loads of the system. The loads forward of the first stage are transmitted by the second-stage rocket nozzle and, forward of the second-stage, bypass the other nozzles and are transmitted by specially designed transition sections. Relative diameters of the various units are also shown in the drawing below, which is to scale. Scout is approximately 70 ft long and weighs about 36,000 lb.

Algol from Jupiter Senior

The first-stage motor, named Algol, utilizes essentially the same hardware developed for the Jupiter Senior by Aerojet. The principal differences are in the number and spacing of bolt holes in the forward and rear rings. A decision was made to shift to the same propellant then being used for Polaris in order to take advantage of all the quality-control procedures and processing experience gained on that program, and to obtain a small increase in performance.

The development program was started by reusing cases already fired in the Jupiter Senior development. Limited qualification tests were conducted at 90, 70, and 50 F. All were successful, but excessive heating at the head of the 50 F motor was detected. It was thought that propellant shrinkage at 50 F had caused separation of the forward insulation from the case. A change was made to allow inclusion of a split boot (CONTINUED ON PAGE 82)

Scout Vehicle to Scale



Solid rockets for spacecraft

Solid-propellant motors give desirable performance in various operations with lunar and planetary vehicles, but also raise special problems, such as low-pressure combustion stability

By Winston Gin and Leonard R. Piasecki

JET PROPULSION LABORATORY, PASADENA, CALIF.

Gin Piasecki

Winston Gin is head of the space vehicles research group in the Solid Propellants Engineering Section of JPL, now an NASA research facility operated by Cal-Tech. His group is responsible for the utilization of solid rockets in JPL spacecraft. Before joining JPL, Gin was a member of the technical staff of the Hughes Aircraft propulsion department from 1953–57, engaged in analysis and preliminary design of Falcon propulsion systems. He received an M.A. in physics from UCLA in 1955 while studying under a Hughes Cooperation Fellowship, and in 1959 he received an M.S. in engineering from UCLA.

Leonard R. Piasecki is chief of JPL's Solid Propellants Engineering Section, responsible for broad support of advancements in solid-propellant rocketry for deep-space vehicles. Formerly, as a group supervisor, he headed propulsion development for the Sergeant missile, the rocket cluster on the Redstone re-entry vehicle, and, in their refinement stages, the upper-stage clusters for Juno I and Juno II rockets. After receiving a B.S. in chemical engineering from Purdue Univ. in 1949, and before joining JPL in 1952, Piasecki was a research chemist with U. S. Steel and the Reynolds Metal Co.

A LARGE fleet of unmanned spacecraft will be launched during the next decade to explore the moon, the nearby planets, and interplanetary space. These spacecraft, fully instrumented and automatic, will execute a midcourse correction maneuver; and many will perform a terminal maneuver to place the craft in its final intended trajectory. The well-established reliability, operational simplicity, and competitive performance of solid-propellant rocket motors recommend them for such propulsion maneuvers.

Consideration will be given here to the requirements of presently planned NASA-JPL lunar and planetary spacecraft missions, to the capabilities of solid rockets to meet these requirements, and, finally, to problems unique or especially significant in the application of solid rockets to spacecraft propulsion.

Some spacecraft have not yet reached the design stage, and it is difficult to specify the propulsion requirements of their various missions without a preliminary system design. Such a system design involves, at least, the following steps: (a) A calculation of booster capability in terms of injected spacecraft weight versus the mission energy requirement; (b) the design of a trajectory which will fall within the limits of astronomical, communications, and tracking constraints, and which will determine the required in-transit and terminal-trajectory corrections; and (c) the preliminary subsystem designs, including propulsion, followed by the spacecraft design integration.

As a further consideration, there is at present some uncertainty about the exact configuration and performance of later-generation boosters like the Saturn. For example, the present staging arrangement of the Saturn C-1 vehicle is optimized for lunar missions. The use of this vehicle for planetary missions without restaging would result in nonmaximized payload weights. Also to be considered are the anticipated advancements in rocketry which will alter the capability of these boosters. These advancements include the possible development of orbital refueling and nuclear upper-stage rockets.

All missions must be evaluated in terms of scientific and technological worthiness after a demonstration of technical feasibility. Operational support and many nontechnical factors must then be

UNMANNED LUNAR SPACECRAFT

Program	Booster	Mission	Injected Weight (lb)	Spacecraft Propulsion
		UNDER DEVELOPMENT		
Ranger (2 flights)	Atlas-Agena B	Escape test probe, 1961 Lunar flyby, 1961	800 800	None None
Ranger (3 flights)	Atlas-Agena B	Lunar rough-landed capsule, 1962	800 (capsule 300 lb with retrorocket)	Liquid midcourse motor —200-lb solid retrorocket
		UNDER STUDY		
Surveyor	Atlas-Centaur	Lunar soft landers	2000–3000	Liquid midcourse and vernier motor, solid retrorocket
Prospector	Saturn C-1	Lunar soft landers	4000–5000	Midcourse, retro, hovering, translating, and vernier propulsion
Prospector	Saturn C-2	Lunar soft landers (mobile laboratory and sample return)	15,000–18,000	Same as C-1 mission with possible inclusion of lunar escape rocket to return sample to earth

UNMANNED PLANETARY SPACECRAFT

Program	Booster	Mission	Injected Weight	Spacecraft Propulsion
		UNDER DEVELOPMENT		
Mariner A-1	Atlas-Centaur	Venus probe, 1962	1100 lb	Liquid motor for multiple midcourse correction; restart experiment near target
		UNDER STUDY		
Mariner A-2	Atlas-Centaur	Deep-space probe	To be determined	Unspecified; midcourse correction probable
Mariner B-1	Atlas-Centaur	Venus flyby		Unspecified; midcourse correction probable
Mariner B-2	Atlas-Centaur	Mars split capsule		Midcourse correction rocket; rocket to split capsule for nonpower landing
Voyager	Saturn C-1	Deep-space probe, Venus orbiter		Unspecified; possible need for midcourse correction rocket, retrorocket, terminal maneuver
Voyager	Saturn C-2	Venus, Mars, and deep-space missions		

considered. Although the propulsion state of the art sets the pace for the feasibility of a mission, it cannot independently dictate the mission's propulsion requirements.

The top table on this spread lists the current best estimates of the lunar spacecraft missions with reference to booster configuration, injected spacecraft weight, and primary propulsion requirements. The table under it lists the same information for the intended planetary spacecraft missions.

The solid-propellant motor can be applied extensively to spacecraft. Among the nonpropulsive applications are gas generation for auxiliary power, spin motors for stabilization and attitude control, thrustors for stage separation, rockets for touchdown stability, and ullage orientation for liquid-propellant tanks. Propulsive applications include retrofiring to place the spacecraft in orbit around the target planet or to land on the moon, trajectory-correction impulsing for midcourse and terminal maneuvers, launching of sub-spacecraft or capsules from the parent probe to a target planet, and powering for lunar or planetary escape to the earth.

Considering the energy capabilities (in terms of injected spacecraft weight) of the boosters listed in the two tables and the intended missions, it can be seen that propellant weights will range from the fractional amounts needed for stabilizing rockets, to about 7000 lb for a Mars orbiter, and to about 11,000 lb for a Saturn C-2 (CONTINUED ON PAGE 52)

Space Flight Report to the Nation Interim Report

SFRN panels to probe space issues

Three unique Space Flight Report panels will explore and interpret space missions, space vehicles, and global impact of space events for the technical community at large

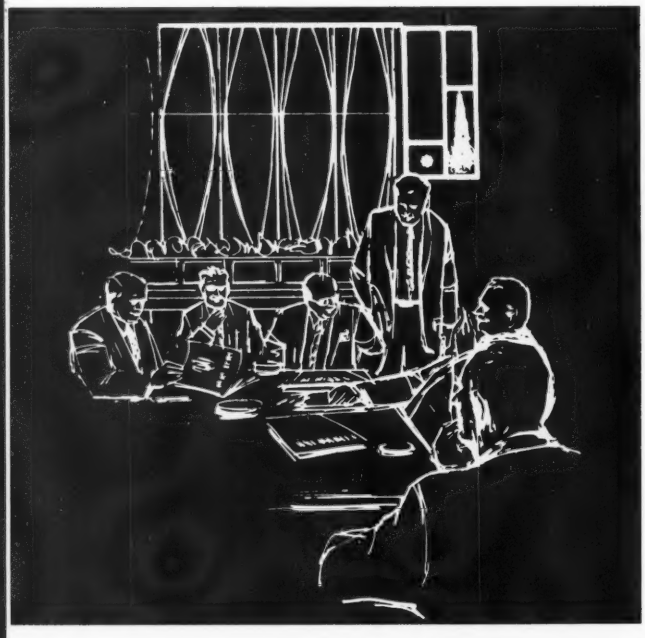
By Rod Hohl

ARS MEETINGS MANAGER

SPACE missions, space vehicles, and the worldwide effects of the space age will be the subjects of three unique interdisciplinary panel discussions planned for the ARS SPACE FLIGHT REPORT TO THE NATION, it has been announced by George Gerard, chairman of the ARS Program Committee.

The vehicles panel will include representatives of chemical propulsion, advanced propulsion, guidance and control, vehicle design and testing, and structures and materials.

Scientists and engineers representing meteorology, geodetics, reconnaissance, navigation, communication, astronomy, and other disciplines will be included in the space-missions panel.



The final panel, which will lead up to the Honors Night address, will look at the broad effects that space flight will have on human society. Included will be experts on international politics, sociology, economics, and communications.

Jerry Grey of Princeton Univ. will be program chairman for the three Space Flight Report panels.

The SPACE FLIGHT REPORT TO THE NATION, which will be held at the New York Coliseum from October 9–14, 1961, will contain three types of sessions: The specialist-to-specialist technical presentations typical of ARS Annual Meetings; the three Space Flight Report panels directed to the technical community at large; and an evening program for the general public.

Six specially constructed meeting rooms will be built on the fourth floor of the Coliseum for the ARS meeting. Technical sessions will be held in these rooms each morning, Monday through Friday, and on Monday and Tuesday afternoons. The special Space Flight Report panels have been scheduled as the only sessions—one a day—for Wednesday, Thursday, and Friday afternoons. The evenings as well as Saturday will be devoted to programs for the public. The Honors Night Dinner will be held Friday evening.

The response to both the SFRN programs and Exposition has resulted in an early demand for available hotel space. Since hotel rooms are particularly scarce in New York in early October, ARS has reserved a block of 3500 rooms for attendees of the SPACE FLIGHT REPORT TO THE NATION. Room reservations can be made through the New York Convention Bureau on the hotel form provided on page 95. ♦♦

Amazing motions of liquid propellants

The great variety and complexity of liquid-propellant motions in rocket tanks must be understood to insure a stable and predictable over-all vehicle performance

By H. Norman Abramson

SOUTHWEST RESEARCH INSTITUTE, SAN ANTONIO, TEX.

THOSE who have attempted to drink hot coffee while riding in today's modern transportation vehicles know that liquids in partially filled containers have an alarming propensity to slosh about, under even the slightest of disturbances. This sloshing sometimes attains alarming proportions, that call for instantaneous corrective action or, lacking this, a hasty mopping-up operation. Liquid propellants in rocket tanks also move about under slight accelerations sometimes causing undesirable performance of the vehicle and even, in extreme cases, catastrophic events.

Unfortunately for the rocket engineer or designer, liquid propellants can exhibit an amazing variety of motions of varying degrees of complexity, none of them really simple and all of them difficult to predict and understand. Nevertheless, much new information concerning these various modes of liquid behavior has become available over just the past two or three years. This paper describes some of

Photo courtesy of Dr. M. I. Yarymovych, Avco Corp.

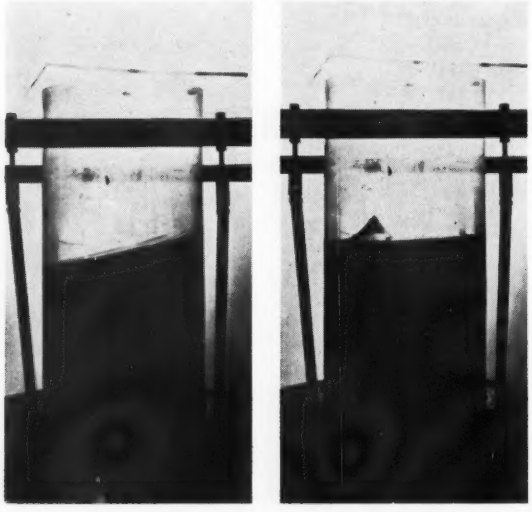
Formation of spray from the liquid free surface when a cylindrical tank is vibrating vertically. This occurs primarily when the tank is being excited with a very high frequency but low amplitude; the spray occurs as the result of an instability of very small ripples on the liquid surface which form under these conditions.

H. Norman Abramson, director of the SRI Dept. of Applied Mechanics, received B.S. and M.S. degrees from Stanford Univ. and a Ph.D. in engineering mechanics and mathematics from the Univ. of Texas in 1956. Before joining SRI, Dr. Abramson was associated with Chance Vought Aircraft during 1951–52 and was associate professor of aeronautical engineering at Texas A&M College from 1952 to 1956. He has published over thirty papers on various subjects in the general fields of applied mechanics and mathematics.

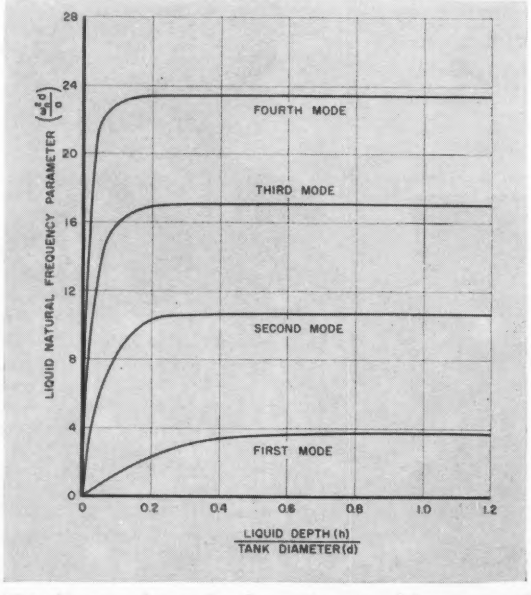
The author would like to express his indebtedness to his colleagues at SRI who have contributed so effectively to its research programs on liquid dynamic behavior over the past four years, and to the former Army Ballistic Missile Agency, now the NASA Marshall SFC, for continued sponsorship of SRI's work.

the more interesting of these problems of dynamic behavior of liquid propellants and, perhaps even more important, indicates various theoretical and laboratory techniques to study them and means to ameliorate their effects on vehicle performance.

Photo courtesy of NASA



First two free-surface modes of liquid motion in an upright cylinder tank. The tank is being oscillated in the direction normal to the tank axis by motion of its base.

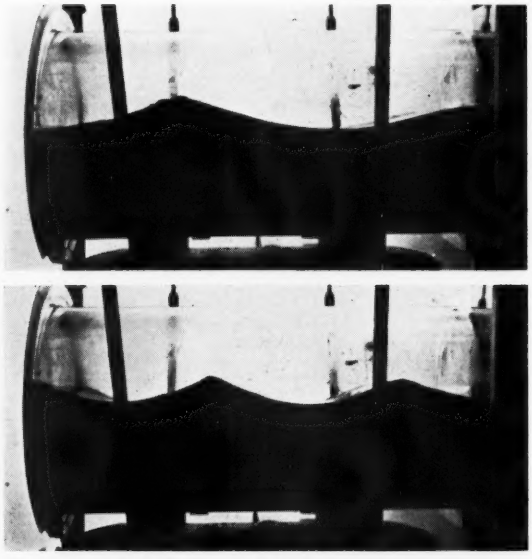


This diagram shows the change in natural frequency of the lowest four of the transverse free-surface modes of motion of a liquid during normal sloshing. The frequency parameter involves the tank size and axial acceleration in order to make it nondimensional, and is plotted against the liquid depth, in terms of tank diameter. Most of the change in frequency occurs for shallow liquid depths, that is, less than one tank diameter for the first mode and even less for higher modes.

"Sloshing" is the term usually applied to the most common type of motion of liquid propellants in partially filled rocket tanks. This relatively simple back-and-forth motion of the liquid, shown in the photos at left, resulting from translational or pitching motions of the tank, is now fairly well understood in terms of its relation to the general dynamical behavior of the entire rocket system and its interactions with other of the system components. Also of importance are such questions as the effects of the liquid motion on boiling and heat-transfer rates for cryogenic liquids, but these are lesser known. One interesting aspect of sloshing in a cylindrical container is the fact that the liquid natural frequencies are dependent upon the liquid depth, as indicated in the graph at left. There is now a relatively complete body of theoretical knowledge available for studying sloshing behavior in tanks of various configuration, as shown below and at the top of the next page, and even such details as wall-pressure distributions are now known. Unfortunately, mathematical theory is not applicable for extremely large amplitude liquid motions, as illustrated on the following page, and hence other techniques of analysis must be employed.

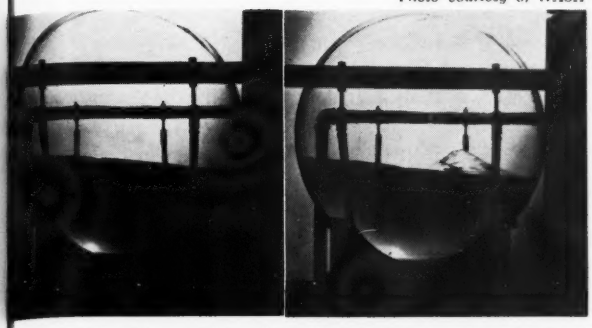
Mechanical suppression devices of one type or another are now almost universally employed in rocket liquid-propellant tanks, shown on the bottom of the next page. Again, the complexity of the

Photo courtesy of NASA

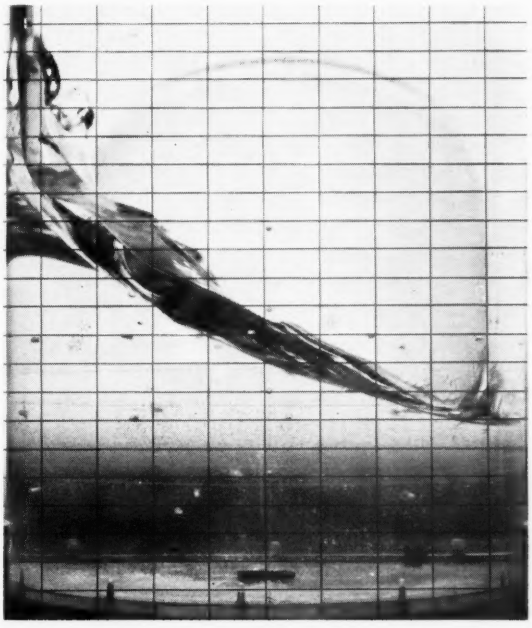


Second and third longitudinal modes of liquid motion in a horizontal cylindrical tank with excitation parallel to the tank axis.

Photo courtesy of NASA



First and second modes of liquid motion in a spherical tank with excitation in the horizontal direction.



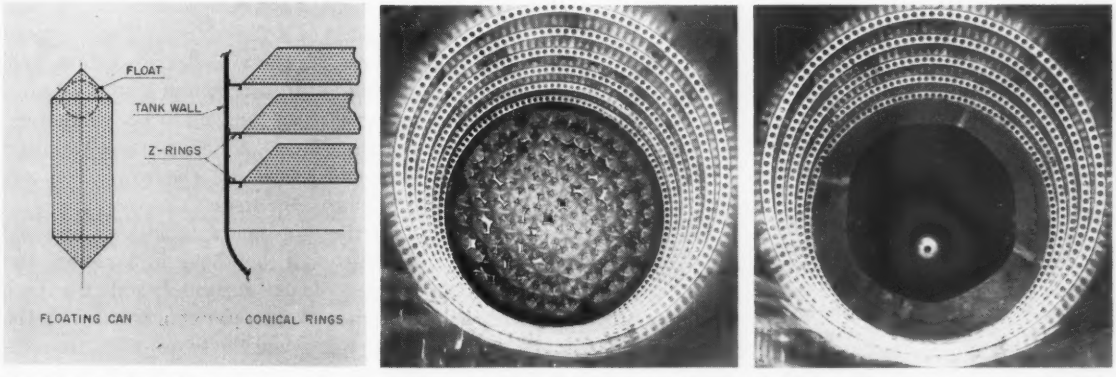
Large-amplitude liquid motion ("breaking" wave) occurring during transverse sloshing near first mode resonance.

liquid-flow behavior in combination with the presence of such devices precludes detailed mathematical study and therefore recourse must be made to experimental investigations. The use of small laboratory models to simulate sloshing behavior has been found quite successful when proper care is given to the selection of the model liquids to insure dynamic similarity with the liquid propellants employed in the actual vehicle. By means of such model studies it is entirely feasible to determine the effectiveness of various suppression devices in terms of damping factors, as shown on page 72. The integration of this knowledge into the problem of analysis of the over-all dynamic behavior of the complete vehicle system, however, is yet a formidable task.

Representing Sloshing Effects

For vehicle dynamic analyses, it is desirable to be able to represent the effects of the sloshing liquid, at least the force and moment that the liquid transmits to the tank, in as simple a manner as possible because of the vast complexity of the over-all system. One valuable technique is to represent the dynamic effect of the sloshing liquid by a set of simple spring-mass-dashpot elements, as shown on pages 72, 74. These can be combined with similar representations for other dynamic elements of the vehicle, and thus the over-all system dynamic behavior can be analyzed by digital or analog techniques.

All of the foregoing has dealt primarily with more or less normal sloshing caused by translational or pitching motions of the tank. Pulsations from rocket engines, or other sources, may, however, lead to considerations of liquid (CONTINUED ON PAGE 72)



Two types of slosh-suppression devices. Both devices are fabricated from perforated material (approximately 25% open) and are quite effective in suppressing sloshing motions by breaking up the liquid surface and providing for much increased viscous resistance: Left, suppressor configurations; center, cans floating on liquid surface inside of model tank; and, right, conical ring baffles mounted in model tank.

Man in space and psychological research

Confusing physiological with psychological research could obscure the meaning of precious data derived from early manned spaceflights

By Charles E. Goshen, M.D.

THE WASHINGTON CLINIC, WASHINGTON, D.C.

Charles E. Goshen is a member of the psychiatric staff of the Washington Clinic and a Professional Associate of the National Research Council's Div. of Medical Sciences. A graduate of Columbia College (1938), Columbia Univ. College of Physicians and Surgeons (1942), and the Psychoanalytic School of New York Medical School (1952), he has served as director of the Nassau Neuropsychiatric Service (1948–57), executive director of the Robins Institute (1953–57), director of the APA's general practitioner education and architecture projects (1957–59), and as consultant to various other institutions. His affiliations include fellowships in the APA and AAAS. Dr. Goshen has authored three professional books and numerous articles, and is on the editorial committee of the journal, "Psychotherapy."

MUCH research going into our man-in-space program is concerned with psychological issues. The specific areas in which it has been foreseen that psychological investigation will be necessary are the selection of personnel for spaceflights, the training of astronauts, reactions to conditions of unusual stress, and human capability as an observer, pilot, and navigator under space conditions.

Many of the problems which the astronaut will have to face have essentially no precedent in our commonplace existence on earth. The new problems which man will have to learn to adjust to will include (1) reaction to extreme degrees of positive and negative acceleration; (2) reaction to zero gravity; (3) reaction to prolonged periods of sensory and social isolation; (4) reaction to an almost totally unfamiliar environment; and (5) reaction to complete dependency upon machine-methods of survival. Other problems of stress will also be met, but are not as unique as these. For example, the obvious uncertainties about making a safe return and the motivational aspects surrounding the pioneering nature of the first flights find equivalents in other areas of human activity.

Various ingenious methods have been devised to simulate the conditions which are likely to prevail in the space vehicle, and preliminary screening for the selection of personnel has already taken place. No experiment has yet been able to duplicate all the predicted features of life in space, but experiments have been contrived that deal with one or another particular facet of the problem. These experiments, regardless of the intentions of those who designed them, will succeed in adding only to our *biological* information, and not to our *psychological* store of knowledge. There appears to be a rather extensive lack of appreciation of the difference between the two; and since this apparent ignorance could undermine the whole research program, we should attempt to clarify the issue.

A convenient way to examine the question of biology as opposed to psychology is to determine first what they have in common, and then to determine how they differ. We can accurately state that both biological and psychological studies of man are concerned with the problem of man's *survival*, and to this extent the two studies are comparable. However, each deals with a separate, independent aspect of survival. Biology studies the survival of man as an animal, and in this respect there exist many helpful parallels between man and other animals, making animal experimentation a useful tool in study-

ing man's biology. The psychological aspects of survival, on the other hand, are those which are concerned with man's humanness rather than his animalness. Those qualities which make man uniquely human and which distinguish him from other animals become the proper area of psychological study.

In brief, we can say that two quite independent sets of goals motivate man's behavior. One points toward his staying alive and well, and this is a subject for biological investigation. The other set is concerned with man's social existence, which is the proper area of psychological investigation.

Since, by definition, none of the qualities which make man human are found in other animals, we can learn little, if anything, from "psychological studies" of other animals. Anything we learn about rats, for instance, can assist our understanding of man's biology, but teaches us nothing about humanity. It is only by studying man himself that we can learn about this quality. If we want to study a simplified prototype of man which is free of some of the complex variables which characterize the typical person, we could select, as our model, a human infant. From such investigations we could, and do, build up our body of basic knowledge of human behavior.

We might also look at the differences between biological and psychological research in another way. The biological makeup of man is determined by a complex interaction of physical and biochemical phenomena, which we call physiology, and these phenomena are related to the biology of other organisms at a chemical level. Man's humanity, on the other hand, is a creation of man's intelligence, and is made up of a complex interaction of social relationships with others. In short, the basic target of biological study is chemistry, and the corresponding target of psychological study is thinking.

Bio-Physio Aspects Play Respective Roles

Biology, having its roots in chemistry, is amenable to many fruitful quantitative measurements. Psychology, in contrast, is rooted in the very essence of all that is qualitative rather than quantitative, namely, human creativity and its product, human society. Man's total social behavior is an outgrowth of the customs, traditions, languages, and institutions which man has fashioned himself with his own creative intelligence; and, invariably, the issues about man's behavior which concern us are the qualitative ones—to put it simply, the goodness and badness of behavior.

The research necessary to provide the information we will need in order to put a man into space must take into account both the biological and psychological aspects of life in a space (CONTINUED ON PAGE 78)

The astronaut challenges once again man's understanding of himself. Above, principles in the approaching man-in-space drama—an astronaut and a Project Mercury capsule mocked up by McDonnell Aircraft for NASA.

The other side of the moon

By Alexander A. Mikhailov

CORRESPONDING MEMBER, U.S.S.R. ACADEMY OF SCIENCES,
DIRECTOR OF PULKOVO OBSERVATORY, U.S.S.R.

ON OCTOBER 7, 1959, when Lunik III was circumnavigating the moon, its automatic twin-lens camera, triggered by a command from the earth, started taking pictures of the moon on standard 35-mm film at a distance of about 65,000 km from the lunar surface. Then the pictures were televised back to earth. The next step was to interpret the picture so as to eliminate possible distortions due to interference and to reveal the actual features of the moonscape.

For the work to be as accurate and complete as possible, the negatives were triplicated and, together with prints, circulated among three research establishments: Pulkovo Observatory (near Leningrad), the Sternberg Institute of Astronomy in Moscow, and the Astronomical Observatory of Kharkov University. Each of these carried on an independent study of the pictures, and their findings were then compared. The most detailed interpretation was undertaken in Moscow with the direct participation of the Central Research Institute of Geodesy, Aerial Photography, and Cartography.

The work has resulted in a catalogue of formations on the moon's hidden side, with the description of every feature and its selenocentric coordinates. The Lunik III pictures covered part of the moon's visible side, including the Sea of Crises, the Marginal Sea, the Smythe Sea, and some other features. This facilitated the identification of the moon's reverse side and the determination of coordinates of the newly discovered features on it.

The catalogue is in three parts, each containing pictures differing in their authenticity. Part I includes features reliably identified on at least three pictures. They total 252, about 100 of which are located on the visible side of the moon. This has served as a control in identification. Part II covers 190 features, each of which is discerned on two pictures, or is poorly visible on many negatives. Part III comprises 57 features identified with the least degree of certainty and whose existence will have to be confirmed in the future. All the features shown on the map on the opposite page are of the lunar hemisphere drawn up in an equatorial orthographic projection.

Atlas Gives Details

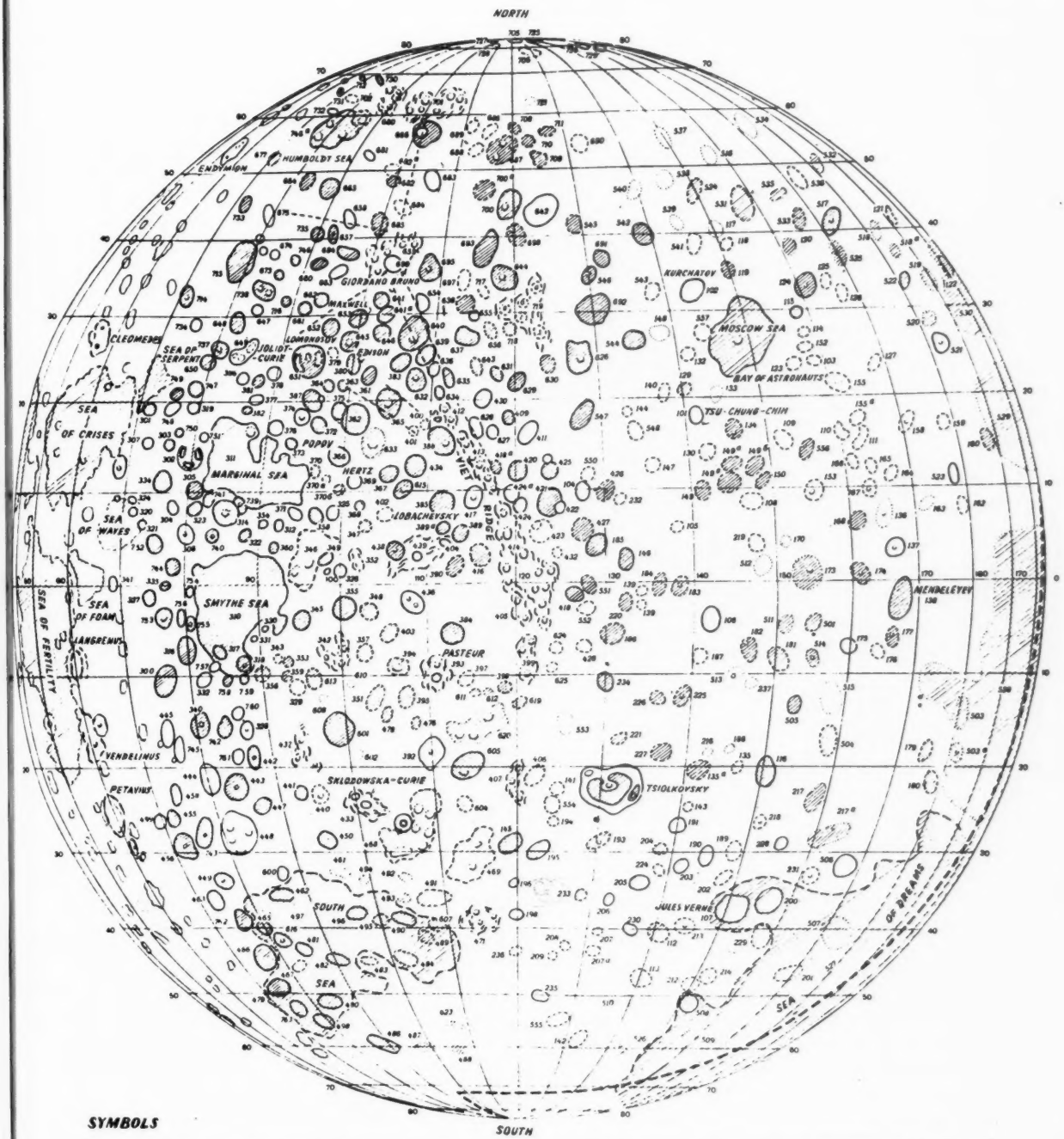
The U.S.S.R. Academy of Sciences Publishing House has put out an *Atlas of the Other Side of the Moon* edited by N. P. Barabashov, A. A. Mikhailov, and Y. N. Lipsky. Apart from the interpretative data mentioned above, the atlas includes large-scale reprints of 30 enlarged photographs which retain all the details of the originals.

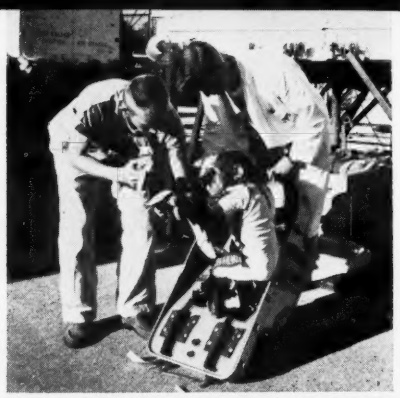
As has been discovered, there is a striking difference between the moon's two faces. The great plains we call "seas" are fewer, and a tableland wrinkled with numerous craters and rings seems to occupy most of the hidden side of the moon.

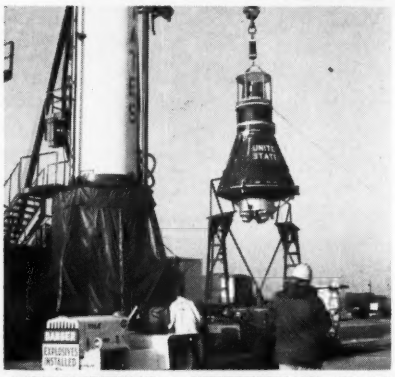
The findings, reported at the International Congress of Astronautics held in Stockholm last August, received high praise from the scientific community. They have marked the beginning of a new era in astronautical astronomy. ♦♦

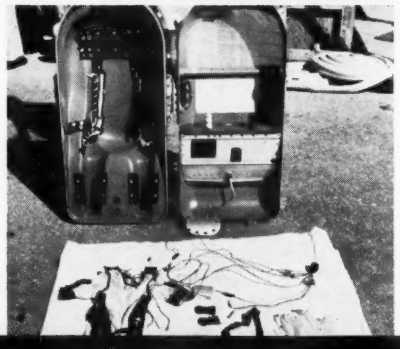
This map was compiled jointly by the Sternberg Institute of Astronomy and the Central Research Institute of Geodesy, Aerial Photography, and Cartography in January-April 1960 on the basis of pictures relayed from the Soviet automatic interplanetary station Lunik III on Oct. 7, 1959. The meridional strip between 30 and 70 deg longitude was compiled according to maps of the visible side of the moon.

Russian Map of the Reverse Side of the Moon



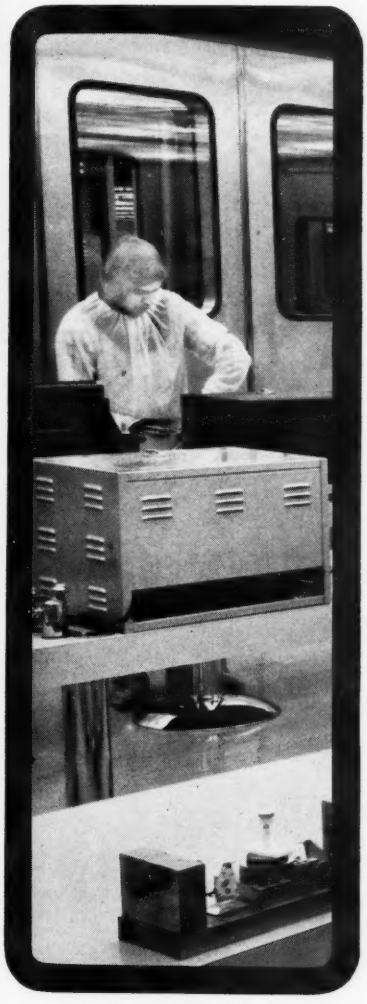


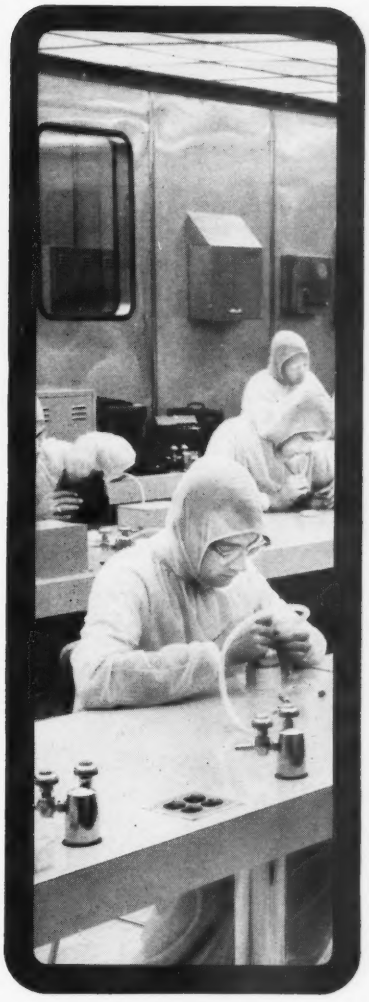




Ham the chimp makes space mark

NASA's second Mercury-Redstone (MR-2) ballistic flight of January 31 some 420 mi down the Atlantic Missile Range put its passenger, Ham the chimp, on record as the largest animal ever to rocket into space, and built an important step on the ladder of flights leading to the testing of an astronaut in the Project Mercury capsule. Just when an astronaut will duplicate Ham's feat in a ballistic flight remains a matter of speculation. Although largely a success, the MR-2 performance showed flaws that may necessitate further chimp flights before an astronaut boards a Mercury-Redstone. But mainly the news was good for Project Mercury. Ham came out of the test well and in fine spirits. And as a consequence, Project Mercury moved a big step closer to manned operations. Shown here, Ham's equipment and some preparation for MR-2. ♦♦





"Delivery room" for a guidance system

Guidance systems and components for some of this country's most advanced ballistic missiles are being born in this room—and no hospital delivery room was ever kept freer from dust and dirt.

It's the "ultra-clean room" at Sperry Farragut—the cleanest of more than 5000 square feet of temperature-controlled clean-room facilities here. Its air locks and dust filters remove from the air all particles larger than 0.3 micron (12 millionths of an inch) and would stop cold the 3-5 micron bacteria dreaded in hospitals. Final assembly of guidance units for the MERCURY and SATURN missiles is carried out here—as well as assembly of a variety of other complex, precision mechanical and electro-mechanical equipment.

This clean room, probably the most advanced in the country in design and construction, is just one example of the ultra-modern facilities for precision military production at Sperry Farragut's 175,000 square-foot Bristol, Tennessee plant. These facilities are manned by a staff with outstanding technical competence and backed by the virtually unlimited capabilities of the Sperry Rand organization.

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The new Burroughs B 5000 Information Processing System is a decided departure from conventional computer concepts. It is a problem-oriented system. Its markedly different logic and language are in large part dictated by the characteristics of ALGOL and COBOL. And it incorporates a complete set of operating, monitoring and service routines.

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More important than these features is the fact that they combine with compiler-oriented logic and language to provide a new concept in computing—an integrated hardware-software system which sets:

NEW STANDARDS OF PROGRAMMING EFFICIENCY

Incorporating logic and language designed to take advantage of modern compiler techniques, the B 5000 permits straightforward, efficient translation of common-language source programs. And it brings a new high in compilation speeds—20 to 50 times faster than those possible on conventional computer systems.

NEW STANDARDS OF AUTOMATIC OPERATION

A Master Control Program, incorporating the automatic operating, monitoring and service routines, is pre-stored on a fast-access drum. It automatically schedules work according to pre-assigned priorities; allocates memory and input/output assignments; and maintains maximum-efficiency use of all components through a comprehensive interrupt system. As a result, human intervention is minimized, system efficiency maximized.

NEW STANDARDS OF PROGRAM-INDEPENDENT MODULARITY

Availability of multiple, functionally independent modules provides the B 5000 with excellent system flexibility and expansibility. The system may include one or two independent processors; up to eight core memory modules with a total capacity of 32,768 48-bit words; and one or two fast-access bulk storage drums, each with a capacity of 32,768 words. Up to four independent input/output channels control a maximum of 26 input/output units, including up to 16 standard-format magnetic tape units. Additional input/output units include card punch and reader, two types of printer, plotter and keyboard.

NEW STANDARDS OF EFFECTIVE MULTI- AND PARALLEL PROCESSING

The Program Independent Modularity of the B 5000, combined with the automatic scheduling and control features of the Master Control Program, permits multi-processing—the B 5000's normal mode of operation. The addition of a second functionally independent processor provides true parallel processing ability.

NEW STANDARDS OF SYSTEM COMMUNICATION

The new B 5000 permits simultaneous on-line/off-line operation. It features completely flexible communication among all of its units. A central processor communicates with all memory units. Any input/output channel communicates with any peripheral equipment and any memory module.

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All of these B 5000 features combine to provide an important new standard of through-put—the maximum amount of work in the shortest possible time, using the fewest possible components. The result is large-scale performance in the medium-price range.

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F-1 Engine Development

(CONTINUED FROM PAGE 25)

of the F-1 engine.

The principal objectives in the design of the F-1 engine are reliability, simplicity, and a degree of ruggedness required to provide a greater margin of safety for future manned applications. Advanced metallurgy, together with proper application of proven component designs, are the tools being used to achieve this goal.

The basic components of the F-1 engine are a tubular-wall thrust chamber, a direct-drive turbopump, a gas generator, and appropriate controls. The engine weighs approximately 15,000 lb.

For simplicity and compactness, the turbopump is mounted directly on the thrust chamber. All other components are either mounted on these two assemblies or are in the plumbing system between them. When the engine is gimballed, the high-pressure ducting is not flexed. Thrust-vector control is achieved by gimballing the entire engine. The high-pressure fuel is used as the hydraulic actuating medium.

The thrust-chamber assembly consists of a tubular-wall, regeneratively cooled chamber with an uncooled extension, a double-inlet oxidizer dome, four integral fuel valves, and a flat-faced injector.

The cooled portion of the thrust chamber extends to a 10:1 expansion area ratio. Its approximate measurements are 40-in. combustion-chamber diameter, $9^1/_2$-ft-nozzle-exit diameter, and 11-ft length. The chamber is designed for the attachment of segmented, uncooled nozzle extensions to facilitate transportation and to accommodate any expansion-area ratio required by the vehicle mission up to 16:1.

This photo shows the regeneratively cooled portion of the F-1 engine's thrust chamber in the process of fabrication.

Two tons per second of liquid oxygen and nearly one ton per second of narrow-cut kerosene (RP-1) are burned in the combustion chamber. The oxygen usage rate is equivalent to that of 60 million people in normal breathing. In three seconds of mainstage operation, the F-1 uses as much fuel as the average automobile uses in one year.

The oxidizer is fed through dual inlets to the dome to assure even distribution to the injector. The oxidizer passes through feed holes, and is injected through a pattern of 2600 orifices into the combustion chamber. The fuel is also fed through dual inlets to a chamber feed manifold, as indicated in the cutaway illustration shown at left. From here, it flows through alternate tubes the length of the chamber, and then returns to the fuel collector manifold. The flow then continues through four valves spaced at 90 deg around the chamber into an injector feed manifold. This manifold distributes the fuel through 32 spokes into the injector, from which it passes through approximately 3700 orifices into the combustion chamber. The location of the valves downstream of the chamber provides a greater degree of control in timing and sequencing the fuel for engine starting. It also provides a repeatable minimum cutoff impulse.

For simplicity and reliability, the turbopump, also shown at left, is a direct-drive unit. The fuel and oxidizer pumps are driven by a velocity-compounded turbine. Operating at rated conditions, it will develop approximately 60,000 hp. It is 4 ft in diam, 5 ft long, and weighs 2500 lb.

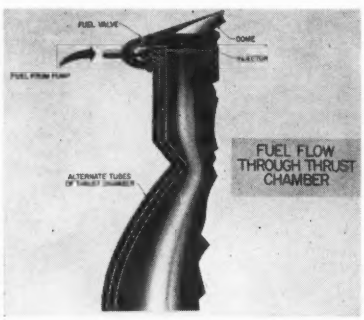
The oxidizer is supplied to the pump through a single inlet, in line with the main shaft, and is discharged radially through dual outlets. The dual-outlet design provides a balance of the centrifugal loads in the pump and minimizes the pump diameter. The fuel-pump design also includes dual inlets and outlets for balanced load distribution and minimum size.

Gas-Generator Operation

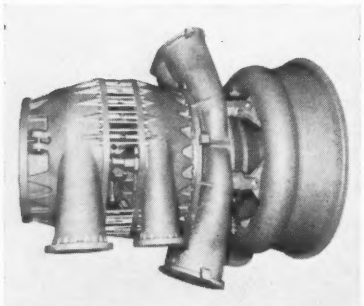
The gas generator, illustrated below, operates fuel-rich, and burns about 2% of the total propellants used in the engine. The partial sphere is approximately 10 in. in diam. The design makes use of a double-wall combustion chamber, through which the fuel flows to cool the body regeneratively. This feature adds to the safety of the engine by eliminating a hot outer surface which could ignite leaking propellants, and it reduces heat radiation to adjacent components.

The main controls are four fuel valves integral to the thrust-chamber

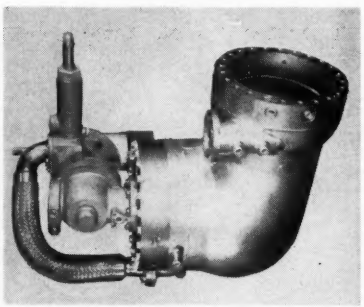
Cutaway of Fuel Flow



Turbopump Mockup



Gas Generator



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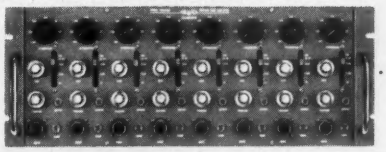

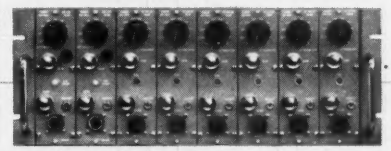

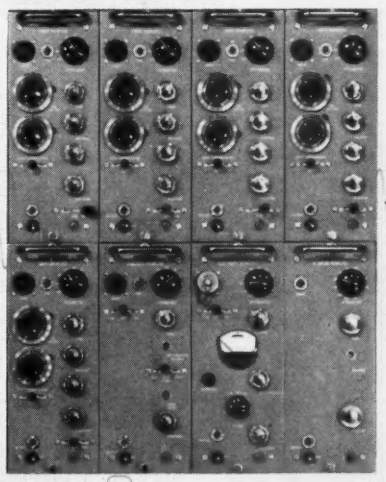

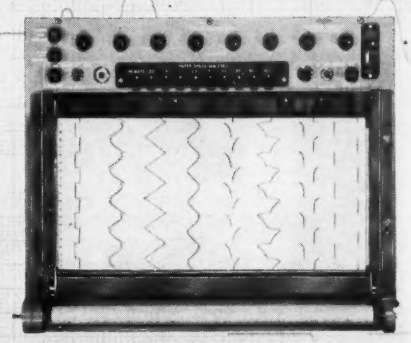

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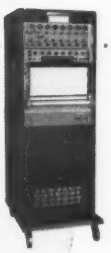
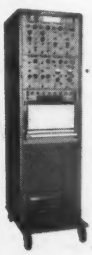
6 or 8 identical DC recording channels — either high gain, 10 uv/div; medium gain, 0.5 mv/div; or low gain, 10 mv/div. Medium and high gain types are completely transistorized, have floating and guarded input circuits. Frequency response DC to 150 cps within 3 db, 10 div peak-to-peak with low and medium gain systems, to 100 cps with high gain system. Amplifier panel space only 7" x 19", recorder 17½" x 19".



850 Series — economical, flexible — miniature plug-in preamps

Interchangeable plug-in preamps, eight to a 7" high module, available in Phase Sensitive Demodulator, DC Coupling, Carrier and Low Level types. System response to 150 cps within 3 db, 10 div peak-to-peak, depending on preamps used. Input circuits single-ended, push-pull, or floating and guarded, depending on choice of preamp.



350 Series — versatile, high performance — interchangeable preamps

Provides greatest possible application flexibility, with interchangeable preamps in Carrier, DC Coupling, Phase Sensitive Demodulator, Differential DC, Low Level, Logarithmic and Frequency Deviation types. System response DC to 150 cps within 3 db at 10 div peak-to-peak — input single-ended, floating and guarded, or push-pull — depending on preamplifier used. Eight preamps in two 4-unit modules occupy 21" x 19" of panel space; usable separately with individual power supplies to drive meters, 'scopes, etc.

"350" style Recorder Assembly — used in all the above systems. Provides transistorized, plug-in, current-feedback power amplifiers . . . low impedance, velocity feedback damped galvanometers . . . 8" of visible record . . . 9 electrically controlled chart speeds . . . inkless traces on rectangular coordinate charts . . . flush front recorder, vertical chart plane. Recorders with horizontal chart plane also available for 350, 850 and 950 systems.

Sanborn oscillographic recording systems also include the tube-type 1- to 8-channel "150" Series with 12 plug-in preamplifiers; and the "650" 1- to 24-channel optical oscillograph with response to 5 KC and 8-channel amplifier available separately for driving any galvanometer. For complete data contact one of the Sanborn Sales-Engineering representatives located in principal cities throughout the United States, Canada and foreign countries.

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assembly, two oxidizer valves mounted on the thrust-chamber dome, a gas-generator valve, a fuel- and oxidizer-flow regulator for the gas generator, and a four-way solenoid valve. This four-way solenoid valve is one of the only two components in the engine requiring electrical wiring or energy; the other is the spark exciter for gas-generator ignition. The oxidizer and fuel valves are of the poppet type. The poppet eliminates the turning moment associated with large butterfly and ball valves, simplifies sealing problems, and minimizes the package size.

The major F-1 engine test facilities consist of two engine stands and a thrust-chamber stand located at Edwards AFB. An interim stand for thrust chambers and a turbopump stand are located at Rocketdyne's Santa Susana facility.

The thrust-chamber test facility capable of the full 1,500,000-lb thrust level that has been provided at Edwards AFB requires huge, high-pressure, heavy-wall tanks to feed the propellants to the chamber. The tanks are constructed of stainless-steel plate approximately 5 in. thick, and have control valves that weigh more than 6 tons each. It was not economically practical to build these tanks large enough to supply the thrust chamber for durations of more than 20 sec.

The engine-test facilities consist of a converted Atlas missile stand and a new two-position stand at Edwards. This new stand accommodates the side-by-side installation of two F-1 engines. This structure is an eleven-story-high complex of heavily reinforced concrete with a girder framework anchored in granite. The stand construction permits the addition of concrete and anchoring structure to accommodate the testing of clusters of F-1 engines.

Injector—A Major Hurdle

Concerning development testing, experience has shown that the injector presents the first major hurdle. Stable combustion must be attained before injector cooling and other thrust-chamber development problems can be investigated. It seems logical to scale up designs which have proved successful in smaller engines. However, this did not prove to be an easy and quick solution for the 400,000-lb-thrust E-1 engine. It took $1^1/_2$ yr to evolve a stable injector configuration for the E-1.

The F-1 injector test program got underway within two months after the start of the NASA contract with the test of full-scale hardware. This was possible because of previous work which provided a test stand and some experimental hardware. Heavy-duty thrust-chamber hardware, which is inexpensive and easily fabricated, was used.

A series of water-flow and calibration tests was conducted to determine the start sequence which should be employed for the first hot-firing test. The initial series of hot tests consisted of ignition and transition tests. This is one of the most critical stages in an injector development program.

Unstable combustion, explosions, and other destructive effects occurred in these tests, which ranged from 100 to 500 millisec in duration. However, a marginal degree of stability was achieved on the third test, and a stable injector configuration was then evolved eight months after the start of the program. A large number of injector tests have now been conducted at or above the 1,000,000-lb thrust level.

The turbopump requires more design and fabrication time than any other component of the engine. To evaluate turbopump-design criteria, an intensive program of model testing was conducted. This model hardware has been successfully used to evaluate the fuel pump, oxidizer pump, inducers, and turbines from the standpoint of performance and durability. First tests of a full-scale turbopump began in November 1960. Calibration and development tests are underway.

Gas-generator tests were started on schedule in March 1960 with a successful short-duration test. Since that date, numerous successful tests have been conducted without failures associated with the combustion process.

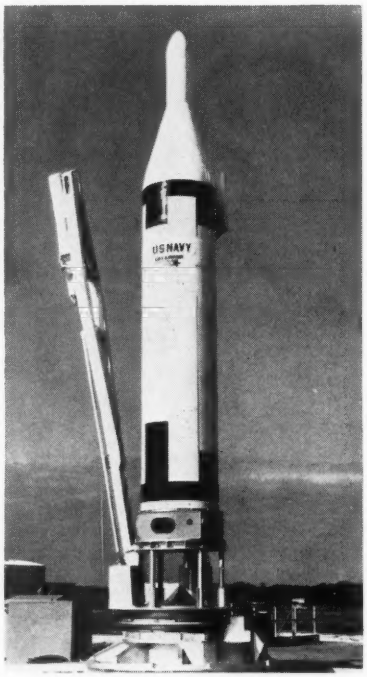
The gas generator has been tested to the full facility capacity of 135 sec, and has performed satisfactorily over wide ranges of mixture ratio, temperature, and pressure. Also included in the test series were simulated engine-start sequences, demonstrating suitability of gas generators for engine use.

The control components, including the oxidizer and fuel valves, the gas-generator valve, the four-way solenoid, and the gas-generator regulators, are all in development testing. These consist of flow, pressure, timing, and actuation tests. In the first phase of testing, water is normally used as the working fluid. However, the development program has progressed to the use of the actual propellant associated with each valve. Prior to installation in the engine, the components undergo tests in the subsystems in which they function. For example, the fuel and oxidizer valves are being tested in thrust-chamber assemblies simulating engine operation, and the valve-assembly regulators are being tested with the gas generator.

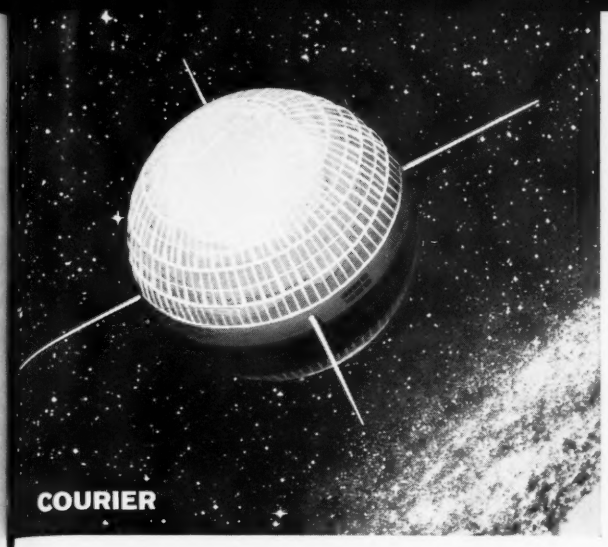
The first engine system is scheduled to be tested early in 1961. The components being assembled into this engine have completed hot-firing and bench tests. The first phase of the engine program will consist of short-duration tests to perfect the engine-start and shutdown sequences. These tests will be followed by performance, durability, repeatability, and reliability programs, all designed to prepare the engine for the start of a preliminary flight-rating test (PFRT) in late 1962. The engine, after approximately 18,000 sec of development testing, is scheduled to complete PFRT tests early in 1963.

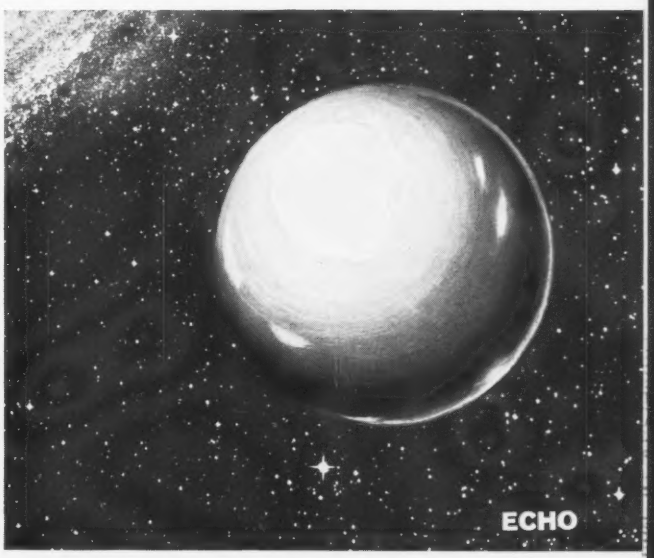
Development of the F-1 engine is proceeding on schedule. With this high-thrust engine available in early 1963, and through the experience gained in engine clustering in the Saturn program, the way will be cleared for launching, in the mid-1960's, of advanced vehicles capable of establishing the first true outposts of man in space. ♦♦

Polaris A-2 1500 N. Mi. Boost



The 1500-n. mi. Polaris A-2, under development for the Navy by Lockheed Missiles and Space Div., as an extension of the program that has already produced an operational 1200-n. mi. submarine-launched ballistic missile rests on a land launching stand at Cape Canaveral. The first A-2 was flight-tested on November 10 last.





Philco Achievements in Space Technology

Philco has made many major contributions to the nation's vital space programs. COURIER, the world's first advanced communications satellite, was designed and built by Philco. Philco played a major role in the development and installation of the complex communications, command, tracking and data systems for the DISCOVERER program. Space-borne and ground communications systems for MIDAS and other satellites have been Philco designed. Philco developed and installed the tracking and receiving systems for the Air Force Passive Satellite Relay Link, which utilizes the ECHO satellite. In the field of human factors engineering, Philco has developed personnel subsystems for several major space projects. Philco also produces the world's largest 3-axis satellite tracking antennas.

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Careers in astronautics

By Irving Michelson, *Illinois Institute of Technology*

THE ENGINEER sits up and takes notice when a prominent scientist regards one of his proudest achievements only to dismiss it as "nothing—the most primitive, halting step." In these terms did an eminent physicist some months ago tweak the engineer's pride, disparaging his hard-won capability for miniaturization. By rearranging the atoms in the way we want, said CalTech's Richard Feynman, we really should be able to write the entire 24 volumes of the *Encyclopedia Britannica* on the head of a pin, or accomplish many other equally astounding feats of ultraminiaturization.

To spark the interest of his audience and readers, Dr. Feynman went so far as to offer a prize of $1000 for the construction of a rotating electric motor $^1/_{64}$-in. cube, which would represent a first stride forward in his range of miniaturization. He also stated that he expected the prize soon to be claimed, and we are recently advised that in this point he was quite right. Engineer William McLellan of Electro-Optical Systems Inc. has taken the prize.

Dr. Feynman, for his part, having made financial as well as theoretical contributions to the furtherance of interdisciplinary progress, immediately withdrew his offer of another prize for a different "first" in advanced miniaturization. Wounds healed and lessons learned, astrodesigners can now concentrate on working toward a big breakthrough in the miniaturization field, an area said to have "*plenty* of room at the bottom."

* * *

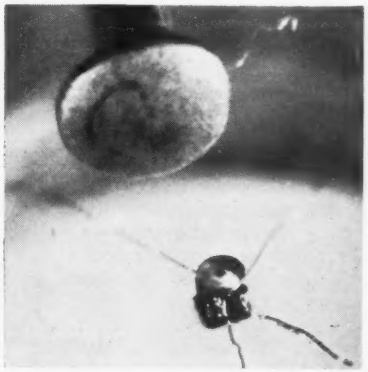
On the subject of the scientist-engineer relationship and "the vanishing engineer," the Air Force Office of Scientific Research recently released its list of research grants. These are grouped under headings starting with "behavioral sciences," "biological sciences," "chemical sciences," and continuing all the way (alphabetically) down to "solid-state sciences," with nary an engineering category shown. As a leading agency in fostering space research, and a former stronghold of engineering research, distributing many millions of dollars to nonprofit institutions and industrial laboratories throughout this country and abroad, AFOSR is still an important factor in setting the tone of important space efforts. One might wonder, from this, whether engineering research and progress has ceased to be a matter of deep concern in some quarters. Perhaps the truth is somewhere to be found between this extreme and the opposite view that, after all, engineers are by now so well indoctrinated in the sciences that they are to be found hard at work in many, if not all, esoteric scientific areas.

* * *

The establishment of techniques and standards for precision measurements is always vital to technological progress, and space-vehicle development has intensified the need for studies in this area. Increased sensitivity and extended range of measurement are required in high-temperature plasmas and exhaust jets, frequency measurements, high-response pressure pickups, and many other applications. Inadequate funding is blamed for the present slump in the National Bureau of Standards' pace in maintaining its traditional position of leadership in setting measurement standards in this country.

In the field of high-temperature measurements, particularly, it is thought that continued Soviet progress has led to a widening "precision gap." Our National Academy of Sciences has been viewing the situation with alarm.

Precision parts in such components as gyroscopes and transistors often require tolerances in hundred-thousandths or even millionths of an inch, creating the need for master gauge blocks accurate within 1 part in 10 million. In an unusual turnabout, we hear that machine-tool manufacturers have given NBS funds to expedite its research in this field. The future need will surely be met, either within government laboratories or outside. We hope that new vitality will be brought to this unique area of applied physics.



A prize piece of work in the wide-open field of microminiaturization—the $^1/_{64}$-in.-cube two-phase, permanent-magnet, synchronous motor designed and built by William McLellan of Electro-Optical Systems Inc.

* * *

Occasionally we are reminded that domestic geography is a factor in space progress. A few years ago there was the cry for decentralization of production effort away from Southern California, and more recently some objections were raised that the East Coast was not contributing its full measure. Now the second-largest state, having suffered serious cutbacks in 1958, which have not yet been restored, is witnessing the formation of a bloc in the Dallas—Ft. Worth area, for the purpose of giving space scientists a little wider choice of employment location and otherwise stimulating a larger portion of aerospace business in that locality. We wish them well.

* * *

NASA has completed studies of inflatable vehicles for bringing astronauts and their equipment safely back from space journeys. Inflatable vehicles offer tempting performance. The large surfaces available after inflation permit pilot control from high altitudes. Total vehicle weight is estimated about 3 tons, less than half of which is required for flexible fabric. Recalling their inflatable airplane design of a few years ago, and the traditional line of other developments in that company, it comes as no surprise at all that the idea was put forward by Goodyear Aircraft. While we can readily see how the adoption of such a concept would relieve many acute design problems now being faced, it may be that a host of new problems will arise with such proposals, and seriously affect all aspects of system design.

For specific career opportunities this month, see Second Cover, pages 15, 22, 52, 53, 59, 65, 67, 83, 85, 91, 92.

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NASA Flight Research Center
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

Solid Rockets

(CONTINUED FROM PAGE 33)

soft-landed lunar spacecraft.

With regard to midcourse propulsion, studies at JPL indicate that, for missions which require only one midcourse correction, the solid-propellant rocket is the lightest (by approximately 25%) and the simplest propulsion system, as compared with liquid monopropellant and bipropellant systems. When more than one correction is required, and when corrections are of the same order of magnitude, the liquid-propulsion systems with restart appear superior in performance because of inherently better propellant utilization. The velocity changes in question are of the order of 100 to 500 fps.

Control requirements placed on the rocket motor in these missions depend on the spacecraft guidance and control capabilities. Propellant temperature must be held to acceptable values in order to provide the required thrust-time characteristics. If extra fuel is present, thrust cutoff on command is required. Adjustment of the thrust level, where vernier rockets are not used, would be required by soft-landing spacecraft to minimize residual velocities or to hover. Performance will be increased in multistage operations by the ejection of spent propulsion hardware. This ejection of hardware would also eliminate an undesirable heat source and an obstacle which could hamper a safe landing or could contaminate the landing site. An ejection operation may be combined with the thrust cutoff.

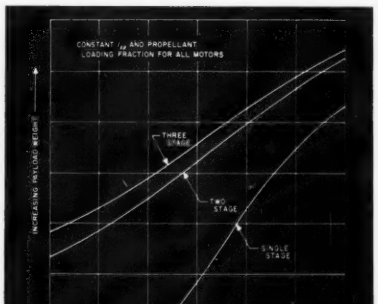
Because of the absence of aerodynamic restoring moments, control of the thrust vector during main-stage burning is a necessity. (The two exceptions are the unlikely possibility that thrust misalignment will not occur and the hypothetical situation of zero burning time.) Without alignment of the thrust vector, torques arising from nominal angular misalignments will impart unacceptably high angular momentum to the spacecraft.

The lunar-impact missions of the Ranger program are typical of the present-generation spacecraft application of high-performance solid rockets. An 800-lb spacecraft, referred to as "the bus," has as its moonbound passenger a 300-lb capsule which separates from the bus in the vicinity of the moon. The capsule is decelerated from the approach velocity of approximately 9200 fps to a nominal zero by the firing of a solid-propellant retrorocket. Errors and uncertainties then allow the buildup of an estimated velocity of 290 fps on landing. Approximately 100 lb, half of which is the payload proper, containing the seismic experiment, is rough-landed on the lunar terrain. This application is representative of present capabilities; with the continued effort to increase propellant specific impulse and to reduce the mass of inert hardware, a constant upgrading of motor performance will accompany spacecraft development.

Certain control capabilities, the lack of which formerly prevented the use of solid rockets, are presently well developed. For instance, several methods for thrust termination upon command are now operational. Thrust-vector control during main powerplant burning may be accomplished by spin-stabilizing the entire spacecraft with small spin rockets (as is done for the Ranger capsule), by vernier rockets, or by some mechanism attached to the main motor, such as a rotating nozzle or secondary fluid injection. Hybrid motors (solid fuel, liquid oxidizer) have been developed with the capability of thrust-level variation upon command, and many alternative schemes are conceivable.

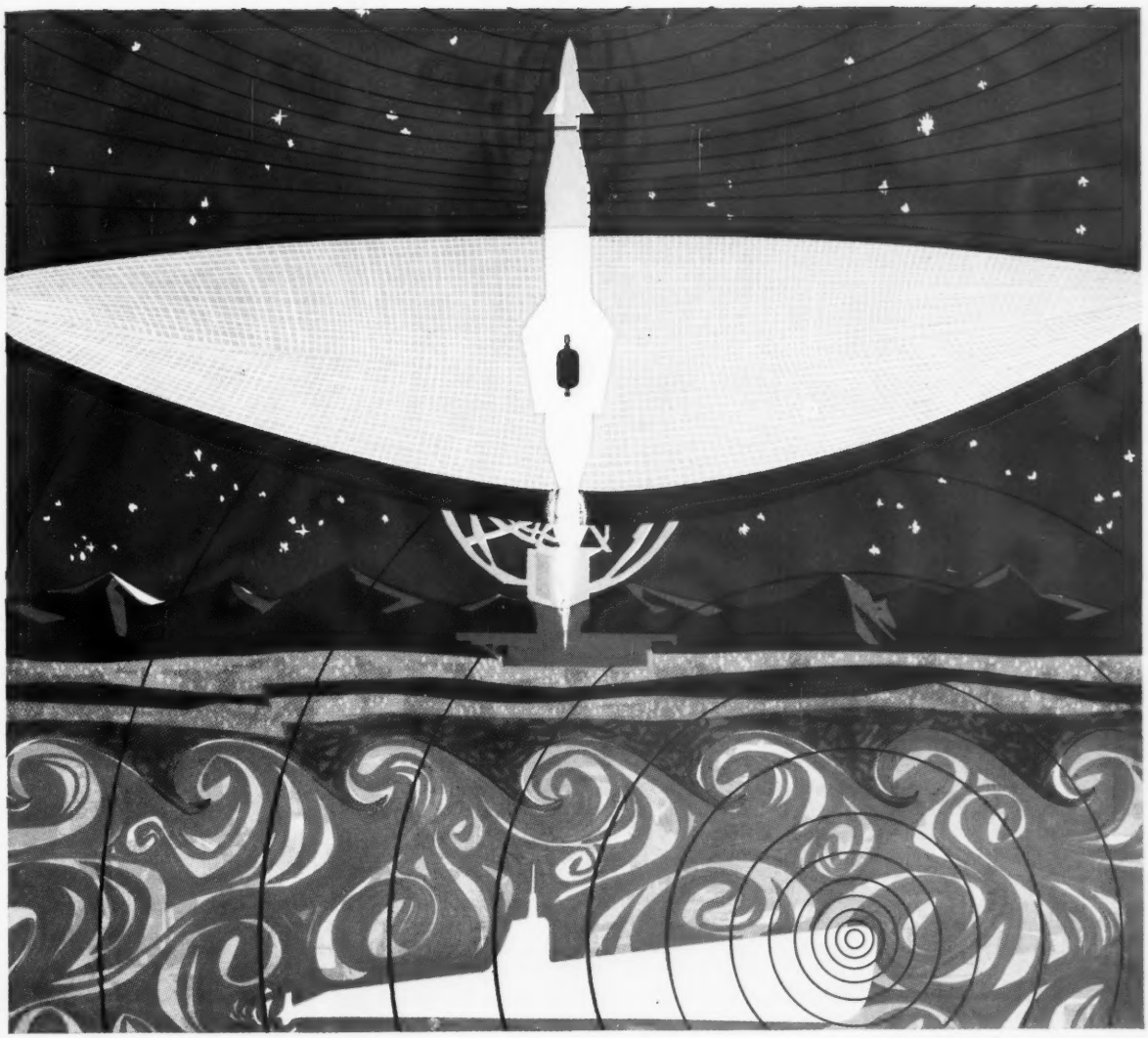
Studies at JPL show that, for missions which require large velocity changes, such as retromaneuvers of high-energy trajectories, the possibility of providing the impulse by firing two or three motors in succession should be considered. The graph below illustrates the significant increase in delivered payload by staging the pro-

Single vs. Multistage Performance



pulsion phase, assuming a given velocity requirement and a given and identical performance capability for each motor. The graph also shows that, as the performance capability (in terms of specific impulse and mass ratio) increases with time, the payload gains resulting from staging will be less appreciable.

Staging to obtain the maximum final payload weight dictates that equal velocity increments must be provided by each stage; therefore, a two-stage system requires two motors of



Brunswick Pioneers Applied Research and Development in Non-Metallics for Aero/Space

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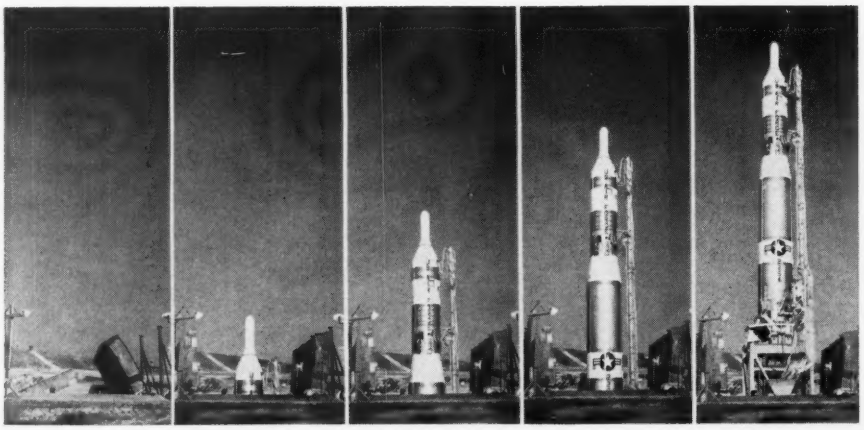
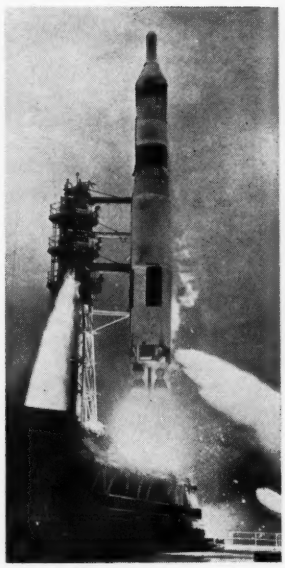
Titan I Pop-Up Operation





Air Force photos indicate elevation of Titan I in a few minutes from underground silo of its Operational Systems Test Facility at Vandenberg AFB, Calif. The silo doors weigh 200 tons. Right, GE closed-circuit television system shot of Titan I launch at the AF Missile Test Center, Cape Canaveral, Calif. The rugged closed-circuit TV cameras made by GE cover Titan operations at Vandenberg and firings at a number of other rocket-test facilities across the country. The first silo in the OSTF was destroyed in development tests early in December 1960.

different size. However, for a comparatively small penalty in payload weight, two motors identical in size can be used instead. A significant increase in payload weight over a single stage is still realized, along with a large decrease in development time and cost, because of the need to develop only one motor. Another approach may be to use a suitable off-the-shelf motor. In this case, one less motor in the staging sequence needs to be developed, affording savings in time and effort comparable to that gained with motors of equal size.

Staging vs. Reliability

The use of more than one stage will decrease the over-all system reliability. However, JPL studies show that a single retrorocket of fixed impulse cannot satisfy lunar soft-landing requirements because of system errors (timing and altitude) in a retrorocket ignition, departures from the nominal approach trajectory, and the inability to correct for impulse variations and horizontal velocity components. For lunar soft-landings a descent using two propulsion systems is the minimal scheme. The time lapse during the burning of the successive stages can be used to gather position and velocity data to effect a successful soft-landing.

There are certain special problems with solid-propellant motors in space vehicles that deserve careful consideration. One is long-term storage in space environment.

A retrorocket motor on an interplanetary trajectory may be in transit for months or years before it has to fire. The storage problems encountered are in many respects different from the surveillance problems for motors here on earth.

Generally, the spacecraft will experience solar radiation, which may be concentrated on one side of the craft and which will vary in intensity with distance from the sun. Radiant energy reflected from a planet may also be appreciable, especially for orbiters. Motors that do heat up under radiation can only be cooled by reradiation. On the other hand, heating of motors may be required after the spacecraft has been in the dark for any significant period of time.

Because solid propellants are temperature-sensitive, motors will require some means of temperature control to insure acceptable physical properties and internal ballistics. Sharp temperature gradients across the grain before ignition should be avoided, and some sensor of effective grain temperature may be required. Possibly insulation with a thin foil or some surface preparation to control the emissivity and absorptivity may be used. As with other applications of solid propellants, the lowest temperature sensitivity would be advantageous.

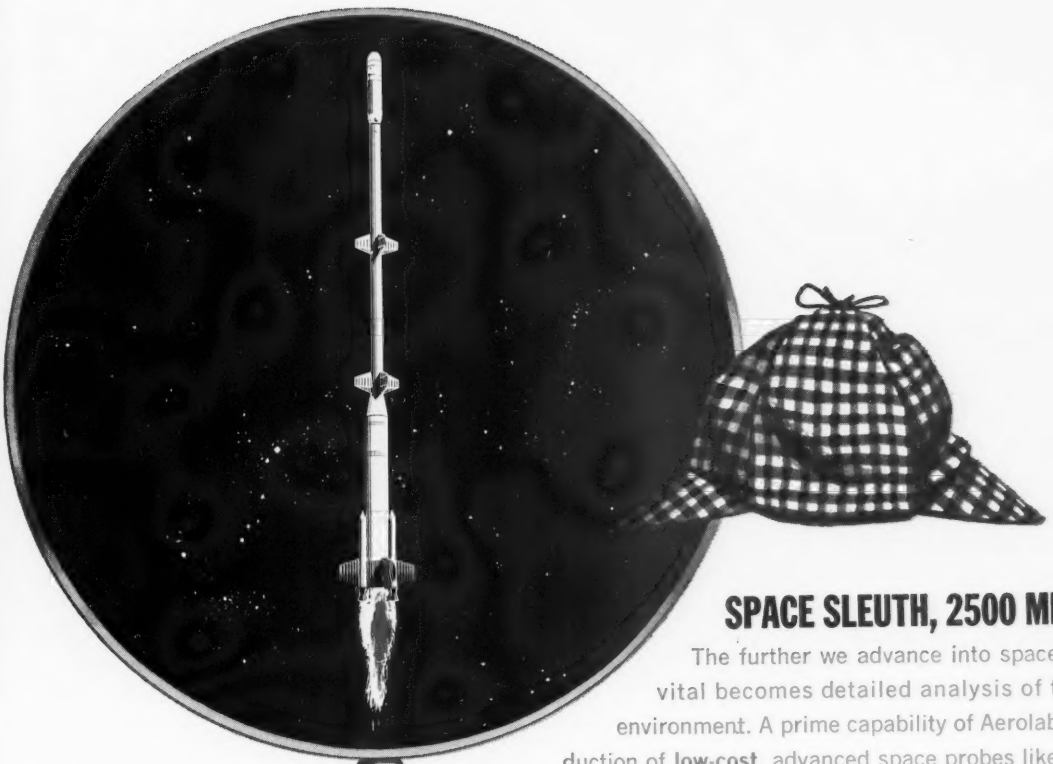
The hard vacuum of outer space poses the possibility of decomposition and evaporation of materials. Some nonmetallic materials, such as plastics, which are ideal for cases and nozzles because of strength and light weight, but which have volatile, low-molecular-weight fractions, must be better understood under the space environment.

For the protection of the propellant and igniter against hard vacuum, the appropriate method appears simply to seal the motor hermetically at the nozzle end and at all other openings. The normal construction of a solid-propellant motor presents a good system for sealing, although there might be problems in sealing against as hard a vacuum as exists in space. A prepressurized motor chamber will facilitate ignition, especially if the motor operating pressure is only a few hundred psia.

Data Needed on Space

There is a lack of definitive information on the possible hazards to solid rockets from meteoroids, cosmic dust, and high-energy radiation. A survey of present knowledge of the space environment and the behavior of materials in the environment has been compiled recently at JPL, and should be published soon. This survey covers galactic cosmic radiation, solar corpuscular radiation, and trapped-belt radiation, which conceivably can break down propellant composition and lead to propulsion-system failure.

The NASA Langley Research Center has studied the effect of the impact of small, high-velocity steel spheres on simulated solid-propellant



SPACE SLEUTH, 2500 MILES UP!

The further we advance into space, the more vital becomes detailed analysis of the spatial environment. A prime capability of Aerolab is the production of **low-cost,** advanced space probes like the famed ARGO D-8 rockets used in NASA's Project NERV. These multi-stage vehicles are the first to measure the nuclear radiation in the Van Allen Belts and to determine its effects upon living organisms.

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THE PROBLEM SOLVERS ... *Ryan Aerolab Offers Challenging Opportunities to Engineers*

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motors at low ambient pressures (NASA TN D-442, by D. J. Carter Jr., Sept. 1960). The impacting spheres succeeded in causing the explosive destruction of some of the target motors. Although by meteoroid standards the velocity of the impacting spheres was low, total kinetic energies —of the order of 10^8 to 10^{10} ergs— were within the estimated meteoroid range. Penetration through the motor wall, or even cratering of the chamber wall, is enough to cause motor failure. Since the meteoroid risk is common to the entire spacecraft, it has been suggested that a meteoroid bumper (perhaps a thin sheet of Mylar) be placed around the spacecraft to shatter meteoroids into smaller particles before the main structure of the craft is hit. Such a bumper would also lessen the hazard of abrasion from space dust and debris. Additional research on the phenomenon of high-speed impact, on meteoroid flux as a function of mass throughout space, and on various engineering schemes for protection is needed to provide data for proper spacecraft design.

Exhaust a Problem

Another special problem is the nearly zero back-pressure of space, which will cause any rocket nozzle of practical length to be underexpanded, and the exhaust plume to fan out. Parts of the spacecraft falling within the exhaust flow field must be designed with consideration for possible blast and heat damage.

Associated with flareout is the problem of having to observe through the rocket exhaust. During the braking maneuver for a moon landing, for example, the thrust cutoff sensor must continually measure the vertical and horizontal velocity components as well as the local altitude. These measurements may be accomplished optically or by means of pulsed or Doppler radar.

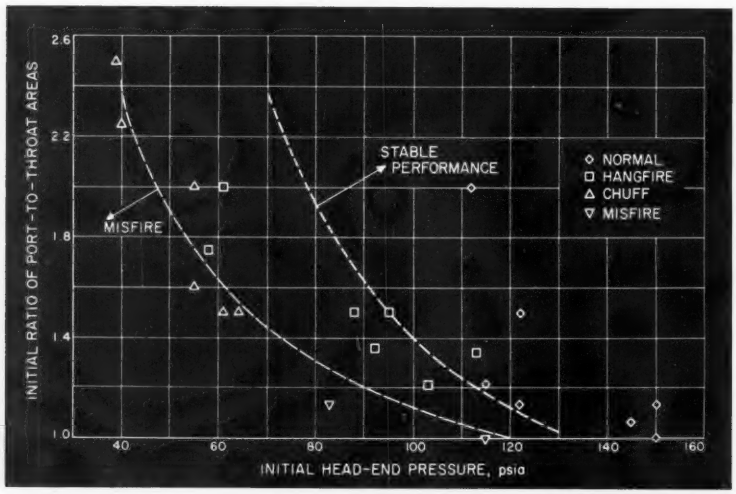
The question arises as to the nature of the interaction of the rocket exhaust products with the signals in producing distortion, attenuation, or spurious noise. Any appreciable degree of ionization and any continuation of combustion in the exhaust flow field would tend to degrade signal transmission. Solid-propellant rockets pose a special problem because of the widespread use of metallic additives in propellant formulations; these yield condensed liquid and solid particles in the exhaust. It is possible, however, that these particles will not follow the expansion of the gases but will flow down a central core through the nozzle. In this case, laterally or angularly displaced sensors may not have to look through the heaviest concentration of particles.

The feasibility of transmission of signals of certain frequencies through exhaust products is a problem that requires more attention. Related to this problem is the possible interference to sensors from dust clouds caused by the firing of retrorockets in the course of landing on the moon or a planet.

As another consequence of low back-pressures in space, combustion-chamber pressures can be low without causing a penalty in performance. The pressure vessel can be lightened, and over-all motor performance pushed higher. Values of chamber pressure suggested for high-performance space rockets range from 50 to 100 psia.

A recent attempt at JPL to reduce chamber pressure in a high-performance motor development revealed an operating condition that prevented sustained stable combustion. During a test of an enlarged nozzle throat, the motor extinguished itself shortly after full combustion. In a subsequent test with an intermediate-sized throat, the phenomenon occurred again, but the motor reignited itself and, after a period of noticeable chamber-pressure oscillation, finally stabilized and burned to propellant exhaustion. Further motor firings with the same propellant, a polyurethane, resulted in data that have been correlated as shown in the graph at bottom. On this plot of the initial ratio of port-to-throat area against the initial head-end chamber pressure, there is a zone of marginal combustion. To one side of this zone the motor will misfire, and to the other side stable combustion will be maintained. These developments indicate that for any propellant being considered for low-pressure operation, a threshold pressure must be determined, below which the thermodynamic efficiency is seriously decreased or stable combustion is uncertain.

Stability in Low-Pressure Combustion



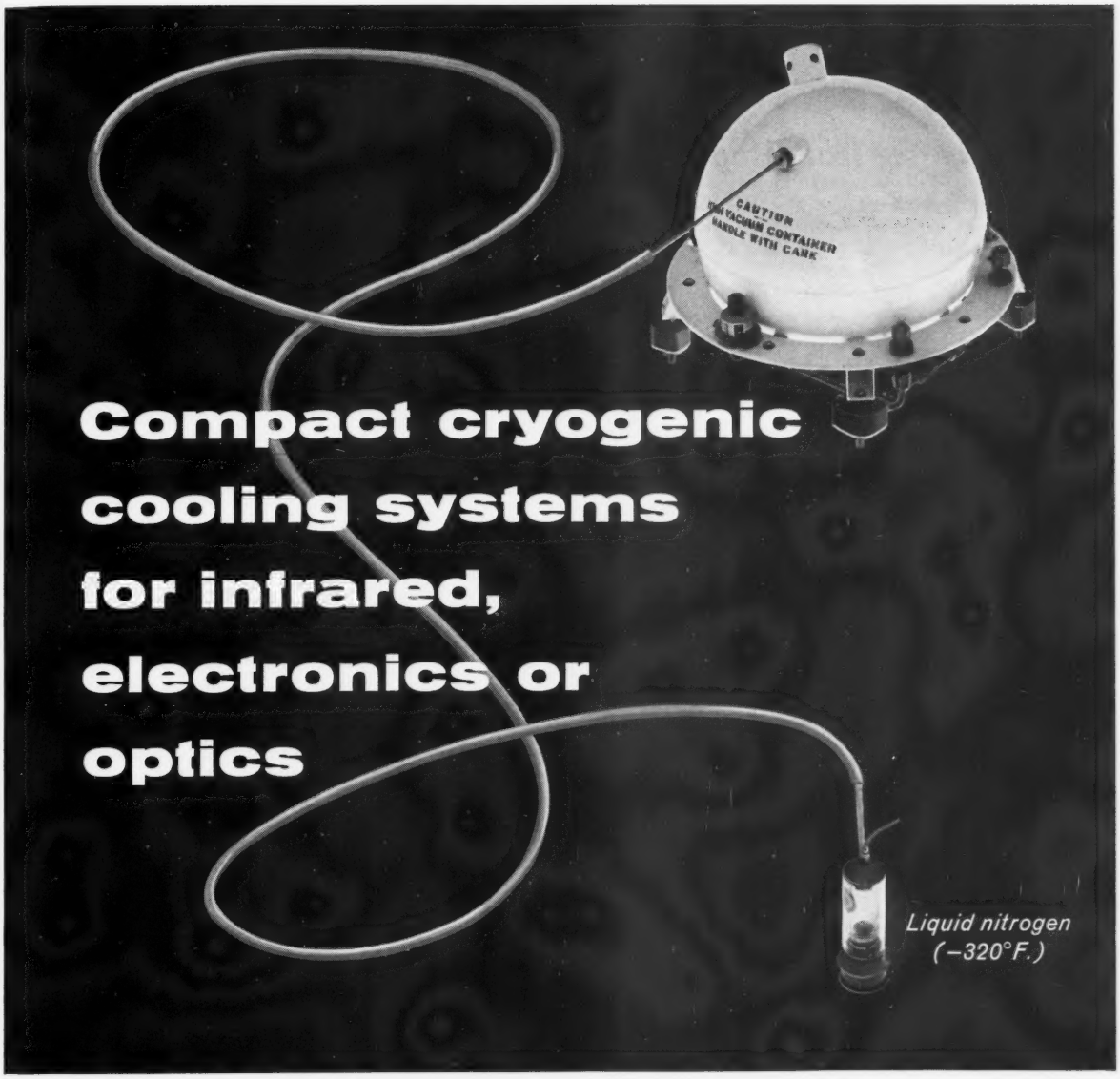
Sterile Propellants?

Finally, it is a policy of NASA that, to the extent technically feasible, all spacecraft on trajectories with the probability of impacting the moon or a planet must be biologically sterilized before launch. The aim is to avoid scientific ambiguity in subsequent investigations of extraterrestrial life. The present belief is that a 24-hr soak of the entire spacecraft at 125 C or a dosage of 10^7 roentgens will be adequate, if such a treatment is practical for all the components of the spacecraft.

The external hardware on the rocket motor may be sterilized with ethylene oxide or some other bactericidal gas or solution. In addition, if it is likely that unburned propellant could survive a landing, the propellant itself may require sterilization. This unusual problem suggests a research program to determine the following:

1. If any or all candidate propellants for outer space are already sterile because of the chemistry of the binder.
2. If the propellant formulation can be modified to include bactericidal agents to assure internal sterility.
3. If the candidate propellants which cannot accept bactericidal agents can be subjected to the suggested heat and radiation treatment with only negligible changes of ballistic and physical properties.

At JPL work has been initiated in some of these several special-problem areas to insure the successful performance of solid rockets for space missions. ♦♦



New AiResearch system delivers nitrogen in liquid form from storage system to cooling area

Now units requiring cryogenic cooling no longer need be designed with allowances made for bulky expanders or adjacent storage tanks.

The new AiResearch system transfers the coolant *in liquid form* to a point of use *25 feet or more away*. The liquefied gas passes through an uninsulated, small, flexible tube which can be bent over and around obstructions. Because the storage system can be placed anywhere, space limitations are overcome and vehicle installation problems are simplified.

The complete system includes the cryogenic liquid container, pressure and flow controls, the liquid transfer tube and cooling adapter. The system can be operated without external power. It can be used with missile, aircraft, space or ground based units and can be converted to a closed-cycle system with the addition of a small gas liquefier.

AiResearch has pioneered many new developments in the cryogenic field. It is presently engaged in work on systems utilizing helium, hydrogen or neon as coolants, and cryogenic systems for zero G operation.

• *Please direct inquiries to Los Angeles Division.*

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

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Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

ARS news

Letter from Headquarters

LAST month we mentioned in this column, with some chagrin, that ARS members had voted down a proposed dues increase from $15.00 to $20.00 by a 2290 to 2030 vote.

An explanatory message from the Board of Directors had been printed on the ballot, giving some of the reasons why it had been necessary to request a dues increase. The point was made, for instance, that ARS had spent at the rate of about $66.00 per member during the previous year, although receiving $15.00 from members and $5.00 from students in dues.

ARS is not unique in this respect. Most, if not all, the societies spend considerably more per member than they receive in dues. Some spend over $100.00 per member, most at least $30.00.

This is as it should be, because societies are nonprofit organizations and the income they receive from advertising in publications and from such things as exhibits enables them to supply services beyond what the members dues could provide.

The October ballot was simply asking the ARS member to pay 30% instead of 25% of what it costs to service him in a year.

The fact that the ballot was defeated makes all of us examine ourselves and wonder whether we're doing our job well enough. Of course, such self-examination takes place continually with any worthwhile organization, but we're looking a lot harder at ourselves in 1961 as a result of this defeat.

Now, to turn this around, we'd like to ask each of the members to look at *himself* to find out how well he is doing *his* job. ARS is, after all, as high in quality as the quality of its members, as energetic as the energy of its members, as conscientious as the total conscientiousness of the members.

We've been reminded by two Presidents recently that the individual has a responsibility to the organization to which he belongs. President Kennedy, in his inaugural address, told 180,000,000 Americans to ask themselves what they can do for their country. ARS President Ritchey, in an editorial in this issue (page 23), tells the 18,000 members (isn't it interesting that exactly one out of 10,000 Americans is an ARS member) that "the next step is up to YOU." We think that both of these admonitions are well taken.

As far as the country is concerned, the *advancement of astronautics* is vital to a strong United States. As far as ARS is concerned, a highly-motivated, conscientious, responsible membership is needed for the *advancement of astronautics*.

One of the big jobs for every one of the 18,000 ARS members is to see to it that every qualified engineer and scientist working in the astronautics field becomes a member of our Society—in other words, becomes a part of the *communications network of the astronautics field*. It seems unbelievable that a mechanical engineer, aeronautical engineer, physicist, chemist, or what have you working in the astronautics field would not beat down the doors of ARS headquarters trying to get an application blank to join, since his very livelihood depends upon effective communications with his field. However, this is not the case—human inertia and all that. It is, therefore, the responsibility of the enlightened 18,000 to carry the word to the probable 75,000 or so who are still outside the fold.

Everyone knows that ARS has grown remarkably—from 7500 to 18,000 members in three years. Here are a few interesting figures on our growth in just a few representative organizations:

	Number of ARS Members	
	1957	1960
Aerojet-General	268	578
American Bosch Arma	19	161
AVCO	19	120
Boeing	68	277
Douglas	117	246
General Electric	224	534
Martin	116	404
North American	301	731
United Aircraft	34	222
and in the government:		
Air Force	194	691
Army	159	265
Navy	125	510
NASA	48	619

This represents quite a growth. However, it also indicates the size of the potential. To have 578 members at Aerojet is indeed impressive and so is 731 at North American and 619 at NASA, but each of these organizations, like most of the others listed above, has several thousands of engineers and scientists working in our field. Surely many of them belong to other societies and feel that they get sufficient technical communications through these, but it's surprising to learn how many of them are not members of *any* society.

The reader might now question: Is this fellow saying that because there are X thousands of people who don't belong to ARS the U.S. space program is not proceeding as rapidly as it should? "Well, of course!"

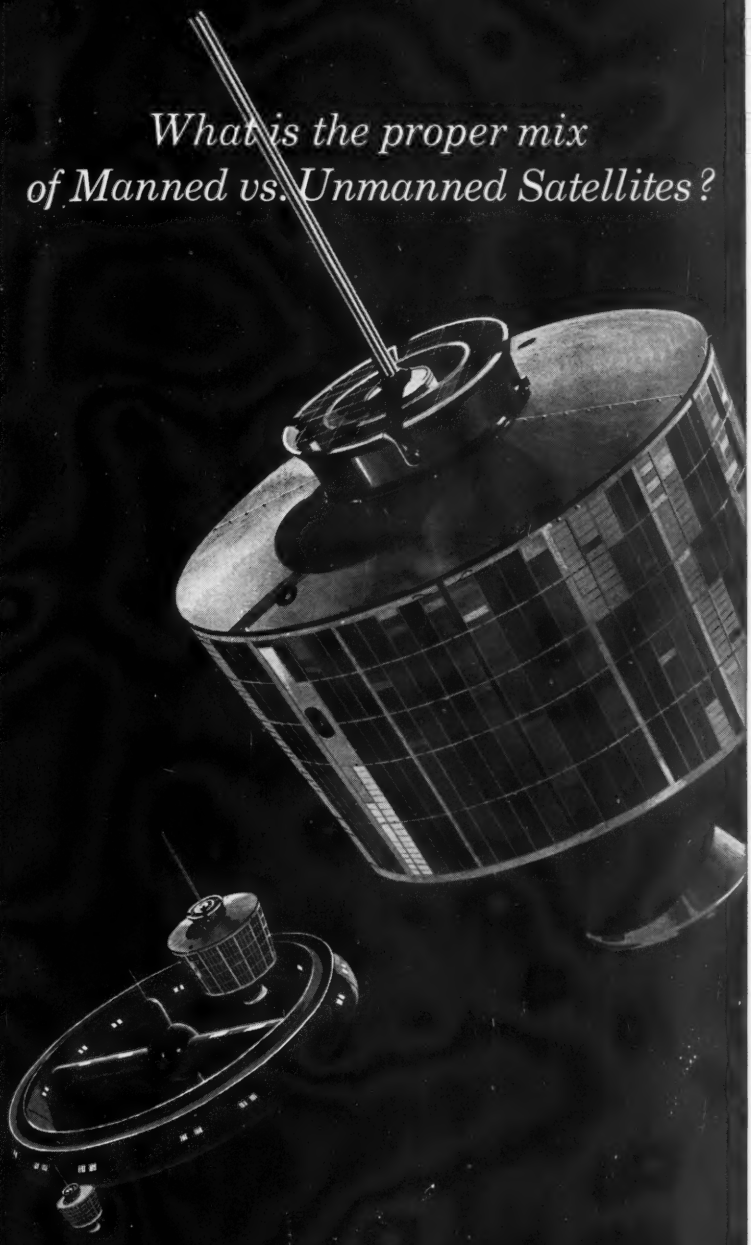
James J. Harford
EXECUTIVE SECRETARY

ARS Missile and Space Vehicle Testing Conference Takes Place This Month

The ARS Missile and Space Vehicle Testing Conference which takes place March 13–16 at the Biltmore Hotel in Los Angeles, Calif., differs from its two predecessors by not singling out one area of test activity for emphasis. The 1961 Conference encompasses a wide range of testing activities. The common denominator for Conference papers will be emphasis on actual test results in significant programs and on state-of-the-art testing techniques.

Why this approach? Added complexity, high costs, and shortened schedules for the development and qualification of today's missile and space-vehicle systems have heightened the need for strong *correlation* of test techniques and test results. How well

What is the proper mix of Manned vs. Unmanned Satellites?



opportunities for

systems analysts

Hughes Aerospace Engineering Division has openings for Systems Analysts to consider and analyze a wide spectrum of basic problems such as:

What are the requirements for manned space flight?

Justify choice of systems considering trade-off of choice in terms of cost effectiveness.

Automatic target recognition requirements for high speed strike reconnaissance systems or unmanned satellites.

IR systems requirements for ballistic missile defense.

Optimum signal processing techniques for inter-planetary telecommunications.

Maintenance and logistic requirements for weapon systems.

The positions involved with the solution of these basic and critical questions present opportunities for the optimum application of the technical and analytical backgrounds of graduate physicists and engineers with both systems and specialized experience.

If you are interested in helping to solve these questions and are a graduate physicist or engineer with a minimum of three years experience in weapon systems analysis, operations analysis, IR, physics of space, signal processing or communication theory, we invite your inquiry. For immediate consideration, please airmail your resume to: **Mr. Robert A. Martin,** Supervisor, Scientific Employment, Hughes Aerospace Engineering Division, Culver City 11, California.

We promise you a reply within one week

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AEROSPACE ENGINEERING DIVISION

On the calendar

1961

March 9–10	Symposium on Engineering Aspects of Magnetohydrodynamics, sponsored by AIEE, IAS, and IRE, Univ. of Pennsylvania, Philadelphia, Pa.
March 13–16	**ARS Missile and Space Vehicle Testing Conference, Biltmore Hotel, Los Angeles.**
March 20–23	IRE International Convention, Waldorf-Astoria Hotel and N.Y. Coliseum, New York, N.Y.
March 27–31	Symposium on Temperature—Its Measurement and Control in Science and Industry, Veteran's Memorial Hall and Deshler-Hilton Hotel, Columbus, Ohio.
April 4–6	**ARS Conference on Lifting Re-entry Vehicles: Structures, Materials, and Design, Riviera Hotel, Palm Springs, Calif.**
April 4–6	Symposium on Electromagnetics and Fluid Dynamics of Gaseous Plasma, co-sponsored by Polytechnic Institute of Brooklyn, IRE, IAS, and U.S. Defense Research Agencies, Engineering Societies Building, New York, N.Y.
April 12–13	Symposium on Information and Decision Processes, Purdue Univ., Lafayette, Ind.
April 18–20	Symposium on Chemical Reaction in Lower and Upper Atmospheres, sponsored by Stanford Research Institute, Mark Hopkins Hotel, San Francisco.
April 26–28	**ARS Propellants, Combustion, and Liquid Rockets Conference, Palm Beach Biltmore, Palm Beach, Fla.**
April 30–May 4	7th ISA National Aero-Space Instrumentation Symposium, Adolphus Hotel, Dallas, Tex.
May 3–5	**ARS/ORNL Space Nuclear Conference, Oak Ridge National Lab, Gatlinburg, Tenn.**
May 8–10	IRE National Aerospace Electronics Conference, Biltmore & Miami Hotels, Dayton, Ohio.
May 9–11	Western Joint Computer Conference, Ambassador Hotel, Los Angeles, Calif.
May 22–24	**ARS National Telemetering Conference, Sheraton Towers Hotel, Chicago, Ill.**
May 22–24	National Symposium on Global Communications, co-sponsored by AIEE and IRE, Hotel Sherman, Chicago, Ill.
June 13–16	**Joint ARS-IAS Meeting, Ambassador Hotel, Los Angeles.**
June 19–21	Heat Transfer and Fluid Mechanics Institute Conference, Univ. of Southern California, Los Angeles.
July 9–14	4th International Conference on Bio-Medical Electronics and 14th Conference on Electronic Techniques in Medicine and Biology, Waldorf-Astoria Hotel, New York, N.Y.
Aug. 7–9	**ARS Guidance and Control Conference, Stanford Univ., Palo Alto, Calif.**
Aug. 16–18	**ARS International Hypersonics Conference, MIT, Cambridge, Mass.**
Aug. 23–25	**ARS Biennial Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.**
Aug. 28–Sept. 1	International Symposium on Rockets and Astronautics sponsored by Japanese Rocket Society, Tokyo.
Aug. 28–Sept. 1	International Heat Transfer Conference, Univ. of Colorado, Boulder, Colo.
Oct. 2–7	**XIIth International Astronautical Congress, Washington, D.C.**
Oct. 4–6	American Society of Photogrammetry Semi-Annual Convention, Biltmore Hotel, New York, N.Y.
Oct. 9–14	**ARS SPACE FLIGHT REPORT TO THE NATION, New York Coliseum, New York, N.Y.**

this correlation is being accomplished and to what extent we can look for future significant advances will be included in eight of the 10 technical sessions scheduled.

Classified sessions covering static testing, flight testing, and specific program experiences should provide pertinent data in keeping with the Conference objective. Unclassified sessions covering testing experiences in guidance and navigation, range operations, human factors, instrumentation, and communications have been arranged to cover other major areas in which testing and test results are significant.

In the support area, a session on propellant handling will cover the problems associated with the handling of new propellants or problems associated with the handling of larger quantities of propellants occasioned by their use in very large rocket systems.

A session on high-altitude simulation testing will provide the latest test results on several rocket programs undergoing this type of testing and future potentials for applying simulation techniques.

Three luncheons have been arranged for the Conference. Luncheon speakers will be Major Robert A. White of AFFTC, Edwards AFB, Calif., who will discuss flight experiences in the X-15 aircraft; and R. C. Seamans, Associate Administrator of NASA, and Vice Admiral John T. Hayward, Deputy Chief of Naval Operations for Research, who will address the Conference on aspects of testing associated with NASA and Navy programs.

A highly informative and interesting Conference is anticipated.

—B. L. Dorman

ARS Lifting Re-entry Vehicles Conference Scheduled for April

Major structural aspects of lifting re-entry will be the main topic of the technical sessions, listed here, at the ARS Lifting Re-entry Vehicles: Structures, Materials, and Design Conference to be held, April 4–6, at the Riviera Hotel, Palm Springs, Calif.

The initial sessions—Design Criteria, Environmental Factors, Materials, Thermo Structural Analysis, and Thermal Protection Systems—are designed to outline several possible approaches or solutions to segments of the overall structural requirements for lifting re-entry. The final (Secret) session—Vehicle Design—will be concerned with integration of these segments into a specific solution for several particular cases.

A keynote address by Alfred J. Eggers of NASA's Ames Research

Center will set the stage for the meeting, and Courtland D. Perkins of Princeton Univ., former AF Assistant Secretary, who has been active in reentry and other space projects, will be the dinner speaker.

Tuesday, April 4

DESIGN CRITERIA

9.00 a.m. **Mediterranean Room**

Keynote Address: Alfred J. Eggers, NASA Ames Research Center, Moffett Field, Calif.

ENVIRONMENTAL FACTORS

2.00 p.m. **Mediterranean Room**

DINNER

7.00 p.m. **Mediterranean Room**

Speaker: Courtland D. Perkins, Chairman, Dept. of Aeronautical Engineering, Princeton Univ., Princeton, N.J.

Wednesday, April 5

MATERIALS

9.00 a.m. **Mediterranean Room**

THERMO STRUCTURAL ANALYSIS

8.00 p.m. **Mediterranean Room**

Thursday, April 6

THERMAL PROTECTION SYSTEMS

9.00 a.m. **Mediterranean Room**

VEHICLE DESIGN

(Secret)

2.00 a.m. **Mediterranean Room**

ARS Standing Committee Chairmen Appointed

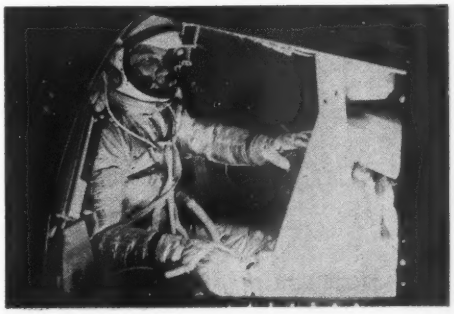
ARS President Harold W. Ritchey has announced the appointment of ARS Standing Committee Chairmen for the coming year. They are: Policy, William H. Pickering; Program, George Gerard; Awards, R. B. Canright; Development, James R. Dempsey; Education, Ali B. Cambel; Finance, Robert A. Gross; International Affairs, A. K. Oppenheim; Membership, A. M. Zarem; Publications, John L. Sloop; Public Education, Arthur B. Kantrowitz; and Section Activities, William J. Cecka Jr. Brooks Morris continues as Coordinator of Technical Committees.

Five More Companies Become Corporate Members

Five more companies have joined the mounting list of AMERICAN ROCKET SOCIETY corporate members participating in Society activities. The companies, their areas of activity, and those named to represent them are as follows:

Ethyl Corporation, New York, N.Y., manufacturer of antiknock compounds and sodium and major supplier of organometallic compounds, antioxidants, vinyl chloride, and other chemicals, is

FOR THE MAN-IN-SPACE MERCURY SPACECRAFT



McDONNELL USES

DORSETT

telemetry components

Dorsett Electronics is responsible for supplying much of the telemetering equipment for the Mercury spacecraft which will be used in the National Aeronautics and Space Administration's "Man-in-Space" program.

For this vital project, distinct and accurate telemetry signals on each channel are an absolute must. Only the highest quality workmanship and electrical performance is acceptable to engineering inspectors for McDonnell Aircraft, prime contractor.

Dorsett has designed, developed and manufactured the transistorized subcarrier oscillators, associated reference oscillator, and power supply mixer-amplifiers that will frequency-modulate and multiplex data in the Mercury manned satellites into transmittible and recordable form. These Dorsett-built components consistently meet McDonnell's standards.

The same high standards of quality and performance extend to the many other telemetering systems and components being supplied by Dorsett for today's advanced aerospace programs. For more information, write today!

DORSETT ELECTRONICS LABORATORIES, INC.

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also active in R&D to meet military missile and space needs. Named to represent Ethyl Corp. in Society affairs are E. B. Rifkin, assistant director of chemical research; H. A. Beatty, staff assistant; R. L. Gealer, contract research; F. Conrad, research supervisor; and D. M. Batson, commercial development representative.

General Precision, Inc., New York, N.Y. is engaged in development of space systems and equipment for navigation guidance and control, computation and data handling; detection, tracking acquisition, and fire-control; simulation, test, and ground-support. Representing the company are R. V. Barnett, GP; D. Balber, Kearfott Div.; R. R. Williamson, Librascope Div.; N. J. Rosenberg, GPL Div.; and W. D. Turner, Link Div.

The Hayes Corporation, Birmingham, Ala., produces missile and aircraft subsystems and components and conducts aircraft maintenance and modification. Company representatives to ARS are Lewis F. Jeffers, president; Nathan V. Vanderlipp, vice-president, manufacturing; William B. O'Neal, senior vice-president; Paul R. Coulson and Benjamin E. Carroll, project engineers.

Technology Instrument Corporation, Acton, Mass., is engaged in research and development and manufacturing of rocket instrumentation. Also designs, develops, constructs, and fires sounding-rocket payloads. TIC is part owner of United Systems Corp., recently formed to produce all phases of rocket systems. Named to represent TIC are H. L. Gray, director of sales; H. Cohen, manager, Space Instrumentation Div.; L. C. Bower, general manager, TIC; J. Frissora and J. King, chief engineer and engineer, respectively, Space Instrumentation Div.

Wyman-Gordon Company, Worcester, Mass., is producer of forgings of all workable metals for the rocket, missile, and aircraft industries, and is currently producing forgings for a majority of the missiles now in use. Representing W-G in ARS are Joseph R. Carter, vice-president and general manager; Albert D. Farnum, manager of public relations; Paul R. Johnson, assistant to the president; James L. Roach, vice-president and director of marketing; and Arnold L. Rustay, technical director.

SECTION NEWS

Central Texas: At a dinner meeting in January, attended by over 50 members and guests, past and future programs of the Section were discussed, and a movie was shown on the Polaris missile.

—C. R. Rowe

Chicago: An overflow crowd of 177 engineers listened with avid interest as Princeton's **Jerry Grey** addressed a joint meeting of the ARS and AIChE in Chicago's Builders' Club in January. Illustrating his talk on "Electrical and Nuclear Propulsion" with a series of excellent slides, Dr. Grey outlined the problems, potential, and prospects of exotic propulsion devices, but assured the chemikers in attendance that conventional rockets would not achieve obsolescence within the next many-several years. International flavor was provided by a "Sehr Herzlichen Dank fur die Freundlichen Gluckwunsche" note from newlyweds Prince Welf Heinrich von Hanover and Princess Alexandre to the Chicago Section.

Future activities of the Section include speeches by President Chuck Miesse to the Iowa-Illinois Section ACS, the Quad-City Science Seminar, and the Tech Society of the Union Special Machine Co. Forthcoming meetings will feature OSR's Milton J. Slawsky, NAA's James A. Hill, and Lane Tech High School's amateur rocket society.

—R. C. Warder

Columbus: In January, an informal dinner meeting was held in the Medallion Room of Pomerene Hall on the Ohio State Univ. campus, with wives and guests invited. Guest speaker **Darrell C. Romick,** an aerophysicist at Goodyear Aircraft, outlined recent developments in space flight and illustrated his lecture with color slides.

—James A. Laughrey

Holloman: At a dinner meeting in January, which included as guests the members of the DOD Scientific Advisory Board—L. D. Carlson, (chairman), Col. Clyde D. Gasser (secretary), R. F. Buchan, J. P. Marbargar, Frank Princi, J. L. Tullis, B. N. Wagner, Richard Lawton, Col. Bollerud, Lt. Col. Almy, C. L. Arnold, W. Greatbatch, Albert Ax, Robert Adams, Miles McLellan, and H. Castillo—the Section heard guest speaker **Norris E. Bradbury,** director of the Los Alamos Scientific Laboratory since 1945, discuss "The Atom in Space." His very interesting lecture was concluded with

This One's for Space

Howard S. Seifert, second from left, immediate past president of ARS, discusses the LR-115 liquid-hydrogen rocket engine with three engineers of Pratt & Whitney Aircraft's Florida Research and Development Center prior to speaking before ARS Palm Beach Section recently. Pictured with Dr. Seifert are, from left, Stanley Mosier, president of the Palm Beach Section; Richard Anschutz, project engineer in charge of LR-115 engine development; and Charles King, vice-chairman of the ARS liquid-propellants committee.

News of Project Orion

Jerry Grey of Princeton Univ. and the ARS Princeton Section discusses Project Orion, the study of nuclear-burst-powered vehicles, before a joint meeting of the Chicago Sections of ARS and AIChE held recently.

slides showing the test facilities at Jackass Flats in Nevada, where the "Rover" nuclear rocket is being tested.

—H. H. Clayton

North Texas: The following new officers have been elected for the coming year: Ronald E. Krape, president; Russell H. Ross, vice-president; Garland B. Whisenhunt, secretary; and Salvatore Caltabiano, treasurer.

Northern California: The Section's first 1961 meeting was held in Palo Alto, Calif., in January. As has been customary for several years, the guest speaker for the January meeting was the newly elected president of ARS for this year, **Harold W. Ritchey.** There was an excellent turn-out of members to hear Dr. Ritchey speak on "Solid and Liquid Propellant Rockets—Where Does Each Belong?" In addition to the technical talk, Dr. Ritchey discussed the workings of the Society and invited members to communicate with the national officers.

Also, retiring Section President Bernard Ellis introduced the new officers: Howard Kindsvater of Lockheed, president; George Edwards of NASA-Ames, vice-president; Norman Fishman of Stanford Research Institute, secretary; and Barnard Iwanciow of United Technology Corp., treasurer.

—Norman Fishman

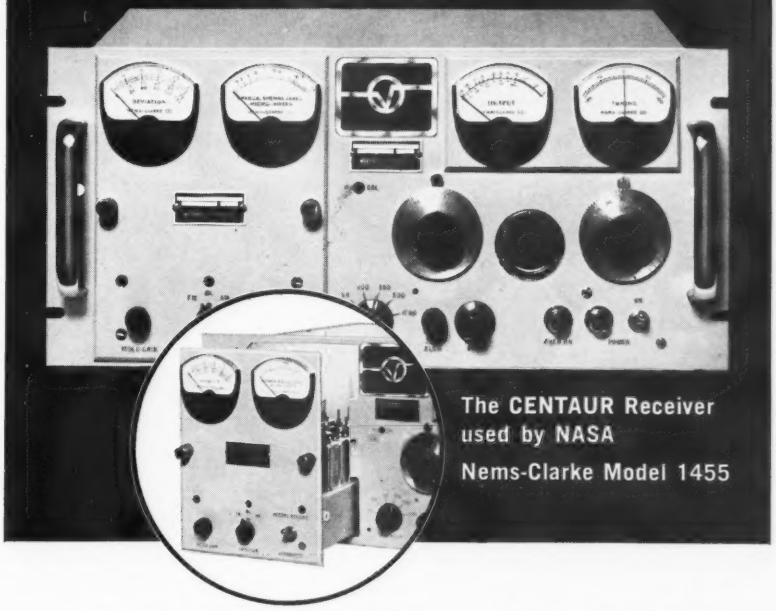
Palm Beach: At the Section's recent annual barbecue, **Howard S. Seifert**—past president of ARS—presented the highlights of the recent national ARS convention in Washington, D.C. Dr. Seifert gave a general summation of the various committee meetings, addresses, and items of special interest which occurred at the convention. He also discussed the functioning of a local section and the aims and objectives of the National Society for the coming year.

—Jack C. Sammons

Princeton: At a joint meeting with the Princeton Chapter of IRE and the Naval Research Reserve Co., an interested audience of almost 200 people heard **John R. Pierce** of Bell Telephone Laboratories discuss satellite communications and Project Echo. As background, Dr. Pierce mentioned that one of the earliest hints of what was being contemplated in space communication was given in 1955 at a similar talk to the Princeton IRE section and published in the *ARS Journal* (then called *Jet Propulsion*).

A general description was given, followed by a detailed analysis of the factors of bandwidth, number of channels possible, power requirements, and antenna and receiver parameters for space satellites. The importance of master receivers in mak-

MODULAR TELEMETRY RECEIVER FEATURES MULTIPLE BANDWIDTH SELECTION



The CENTAUR Receiver used by NASA
Nems-Clarke Model 1455

Designed to provide a selectable bandwidth capability for PCM, the 1455 most nearly approximates a "universal" telemetry receiver. IF/Demodulator Modules are available in bandwidths ranging from 100 KC to 1.5 MC. Each module contains 3 independent demodulators. Selectable by a front panel switch, they are: Foster-Seeley Discriminator, Phase-Lock Detector, and AM envelope detector. As a further refinement in signal-to-noise ratio enhancement, the video amplifier incorporates a video bandwidth filter having a 6 db per octave roll-off adjustable from 20 KC to 1.2 MC by means of a front panel switch. This receiver is capable of **optimum** reception of any known type of telemetry signal. Features: 5 MC pre-detection recording output, playback input terminals, and integral VFO, automatically actuated by a micro-switch on the crystal socket. The modulation sensitivity and deviation meter scales provide output voltages and meter deflections which are essentially the same percentage of bandwidth in all modules.

Available as an accessory unit is the Nems-Clarke IFC 1400 Pre-Detection Converter which permits use of the 1455 with stationary-head instrumentation tape recorders for pre-detection recording.

See the 1455 Receiver at the I.R.E. Show, Booths 3917-3919.

Vitro ELECTRONICS A DIVISION OF VITRO CORPORATION OF AMERICA
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1961 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
March 13–16	Missile and Space Vehicle Testing Conference	Los Angeles, Calif.	Past
April 4–6	Lifting Re-entry Vehicles: Structures, Materials, and Design Conference	Palm Springs, Calif.	Past
April 26–28	Propellants, Combustion, and Liquid Rockets Conference	Palm Beach, Fla.	Past
May 3–5	Space Nuclear Conference	Gatlinburg, Tenn.	Past
May 22–24	National Telemetering Conference	Chicago, Ill.	Past
June 13–16	Joint ARS-IAS Meeting	Los Angeles, Calif.	Past
Aug. 7–9	Guidance and Control Conference	Palo Alto, Calif.	March 15
Aug. 16–18	International Hypersonics Conference	Cambridge, Mass.	March 31
Aug. 23–25	Biennial Gas Dynamics Symposium	Evanston, Ill.	Past
Oct. 2–7	XIIth International Astronautical Congress	Washington, D.C.	May 1
Oct. 9–14	ARS SPACE FLIGHT REPORT TO THE NATION	New York, N.Y.	April 15

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.

ing successful operation possible was stressed. Mention was also made of the functions served by both passive and active satellites and the relative merits of each method. Some of the experiences with Project Echo were described, and the talk was concluded with a description of a generalized approach for the future active satellite systems being considered. After the meeting, refreshments were served through the courtesy of the IRE section, host for the evening.

—H. M. Gurin

Sacramento: At the November meeting, which was attended by a record audience of 228 members and guests, guest speaker **Fritz Zwicky** of CalTech spoke on "Exploration of the Universe." Dr. Zwicky illustrated his talk with slides. He discussed the nature of the universe and the galaxies and the manner in which astronomers learn about the universe, including the use of telescopes, photographs, and spectroscopy.

Utah: In January, some 100 members and guests attended the Section's installation dinner at the Hotel Utah in Salt Lake City. Special guests of honor included George D. Clyde, governor of the state of Utah; Ray Olpin, president of the Univ. of Utah; John Higginson, general manager of Thiokol Chemical's Utah Div.; Edward Nauman, general manager of Thiokol's Wasatch Div.; John Greer, general manager of Hercules Powder Co.; and Donald Tasker, general manager of Marquardt Corp.

The evening's guest speaker was **Edward Flesh,** McDonnell Aircraft's engineering manager of Project Mercury, who discussed the history of the man-in-space program and the technology of the Mercury capsule.

—John P. McGovern

STUDENT CHAPTER

Univ. of Michigan: The 5th annual joint meeting with the Detroit Section was held by this Chapter in Kellogg Auditorium in January, and was preceded by a banquet. The speaker for the evening was **Emerson W. Conlon,** NASA assistant director of research, who discussed "Advanced Propulsion."

—Judith M. Forde

TECHNICAL COMMITTEES

The ARS/ORNL Space Nuclear Conference, that is scheduled for May 3–5 at the Oak Ridge National Laboratory in Gatlinburg, Tenn., will be a focal point for the activities and planning of the ARS Nuclear Propulsion Committee, chaired this year by **Robert Bussard** of LASL. The NP Committee will meet in March at the IAS Flight Propulsion Conference in Cleveland, the ARS/ORNL Conference, and the ARS Annual Meeting and SFRN, according to Chairman Bussard. It is working on two unclassified sessions for the SPACE FLIGHT REPORT TO THE NATION and laying the foundation for a specialists conference on nuclear propulsion to be held in 1962. The NP Committee does not plan to participate in the joint ARS-IAS Semi-Annual Meeting to be held during June in Los Angeles.

"Instrumentation for Space Physics" will be the subject of the session being organized by the Physics of the Atmosphere and Space Committee, chaired by **Herbert Friedman,** for the joint ARS-IAS Semi-Annual Meeting in Los Angeles. The PAS Committee plans three sessions for the Annual Meeting and SFRN to survey knowledge in the following nine areas of space research: Atmospheric structure, ionosphere, airglow and auroras, solar radiation, dust and meteorites, Van Allen belts, magnetic fields, interplanetary medium, and the moon

CHANGE-OF-ADDRESS NOTICE

In the event of a change of address, it is necessary to include both your old and new addresses, as well as your membership number and coding, when notifying ARS Headquarters in order to insure prompt service. If you are moving or have moved, send the following form to Membership Dept., American Rocket Society, 500 Fifth Ave., New York 36, N.Y.

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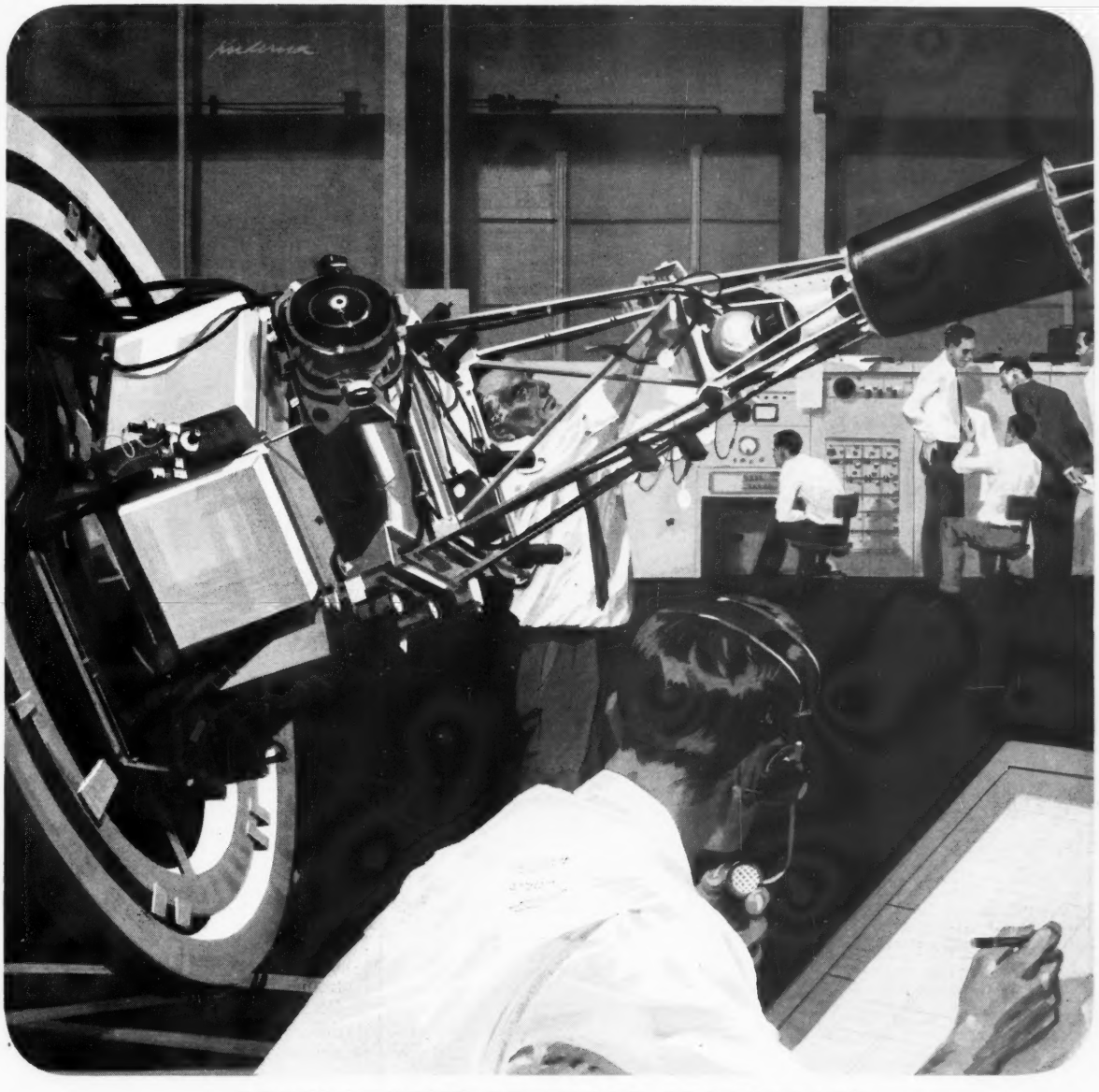
PIONEERING IN SPACE RESEARCH



DEVELOPMENT OF LUNAR SPACECRAFT

The "Ranger" series of spacecraft, designed first to explore the environment and later to land instrument capsules on the Moon, are now being developed and tested at Jet Propulsion Laboratory.

Illustrated is a "Ranger" proof-test model undergoing design verification testing at the Laboratory. Here design features are tested and proved, operational procedures developed and handling experience gained for the actual construction of the initial flight spacecraft.

This is one phase of JPL's current assignment from the National Aeronautics and Space Administration—to be responsible for the Nation's unmanned lunar, planetary and interplanetary exploration.

An advanced program such as this provides numerous objectives and incentives for qualified engineers and scientists who are eager to help solve the complex problems of deep space exploration.

Such men are welcome at JPL.

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and planets. Each of these sessions will include three 45-min lectures.

The Human Factors and Bioastronautics Committee, chaired by **Eugene Konecci,** is sponsoring a session at the ARS Missile and Space Vehicle Testing Conference, being held this month, March 13–16, at the Biltmore Hotel in Los Angeles; will work with the IAS to organize two sessions for the joint Semi-Annual Meeting coming up in Los Angeles in June—titles, "Space Physiology and Performance" and "Space Operations and Maintenance"; and is discussing a number of panels, reviews, and sessions for the Annual Meeting and SFRN. Also, the HF&BA Committee has tentative plans for a specialists meeting to be held in conjunction with the meeting on nuclear propulsion in 1962. In a recent progress report, the HF&BA people expressed appreciation for Lt. Col. Stanley White's leadership of the Committee during 1959 and 1960, and wished him and the NASA Space Task Group good luck and Godspeed on Project Mercury.

CORPORATE MEMBERS

Collins Radio Co. has consolidated the service activities of Collins Western, Texas, and Cedar Rapids Divisions and those of its subsidiary, the Alpha Corp., into the newly created Service Div. . . . **Douglas Aircraft Co.** has begun the first phase of a $2-million modification program at its Sacramento field station in preparation for system and static testing of the Saturn S-IV and future space vehicles . . . **GE**'s Computer Dept. plans a $4 million addition to its manufacturing and headquarters facility at Phoenix, Ariz. . . . **General Dynamics Corp.** has announced creation of a new division, General Dynamics/Electronics, which will consolidate electronics activities of its various divisions. The company has also established a GD/E graduate fellowship in electrical engineering at Syracuse Univ., and has renewed a similar grant to Cornell Univ. Each of the fellowships carries a stipend of $2400, plus full tuition and all fees.

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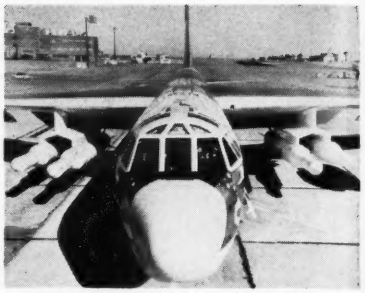
Transition



The first production model of the Boeing B-52H, with a range well over the 10,000 mi of earlier models, lines up with load of four dummy 1000-mi Skybolt air-launched ballistic missiles, developed for the Air Force by Douglas. Skybolt will become operational in about three years.

Grumman Aircraft Engineering Corp. has let bids for construction of an "Environmental Space Chamber" . . . **ITT** and **Texas Instruments Inc.** have announced an agreement to exchange non-exclusive patent licenses and technical information concerning semiconductor components . . . **IBM** will present $275,000 in awards to 250 employees to inaugurate its Invention Award Plan, a new program designed to encourage inventions and which is open to all employees of IBM and its domestic subsidiaries. The IBM Federal Systems Div. has set up a new Communications Center . . . **Lear, Inc.**, has established an annual award, a 36-in. high silver trophy, for the most significant achievement in the field of air traffic safety . . . **McDonnell Aircraft** has formed an Electronics Equipment Div. . . . **Northrop Corp.** announces that its multimillion dollar hypersonic wind tunnel, capable of speeds up to 10,640 mph, will become operational at its Norair Div. early next year . . . **Raytheon Co.** has opened its new headquarters at Lexington, Mass. Directors of the company have approved the aquisition of Trans-Sil Corp., Englewood, N.J., manufacturer of high power silicon rectifiers. ♦♦

ARGMA Readies Environmental Missile Test Facility

The Army Rocket and Guided Missile Agency, Huntsville, Ala., will soon put into operation the country's most comprehensive facility for environmental testing of missiles with loaded motors, in envelopes up to 36 ft long and 8 ft in diam. A full gamut of tests on a missile will run 28 days consecutively.

Said Gaspard de Coriolis: *"A particle which is subject to no forces in a rotating coordinate system experiences a radial acceleration and a tangential acceleration."*

It was around 1840 that Coriolis discovered what has since become known as the Coriolis Effect. He noticed objects above the earth tend to rotate relative to the earth's rotation . . . to the right in the northern hemisphere, to the left in the southern.

The Coriolis Effect is in force in outer space, too. If a space vehicle is rotated in order to establish artificial gravity, the necessarily short radius of the rotation causes a Coriolis force. This creates orientation problems for a human occupant. To eliminate this difficulty, a scientist at Lockheed Missiles and Space Division conceived the idea of connecting the vehicle to an auxiliary fuel tank by a half-mile-long cable. Thus, if the whole system is then rotated at a reduced speed around its center of mass gravity, the longer radius greatly minimizes the Coriolis force. Right now—on the drawing boards at Lockheed—is an enormously advanced space vehicle system which utilizes this concept, in addition to many others.

Fortunately, natural laws are about the only restrictions which circumscribe scientists and engineers at Lockheed Missiles and Space Division. The climate in Sunnyvale and Palo Alto, on the San Francisco Peninsula, is close to perfection. The creative atmosphere—the opportunity to work on such important projects as the DISCOVERER and MIDAS satellites, the POLARIS FBM, or even more advanced concepts such as the space system cited above—is the dream of the creative engineer.

Why not investigate future possibilities at Lockheed? Write Research and Development Staff, Dept. M-11A, 962 West El Camino Real, Sunnyvale, Calif. U.S. citizenship or existing Department of Defense industrial security clearance required.

Lockheed / **MISSILES AND SPACE DIVISION**

Systems Manager for the Navy POLARIS FBM and the Air Force AGENA Satellite in the DISCOVERER and MIDAS Programs

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA • CAPE CANAVERAL, FLORIDA • HAWAII

The Agena Engine

(CONTINUED FROM PAGE 29)

Another key component was the turbine pump, which consists of a single-stage impulse turbine operating on combustion products of the bipropellant gas generator. The pumps discharge through diffuser-type ports, which, in the pump system, perform like cavitating venturis. Cavitation occurs in the venturis when the static pressure at the throat is reduced to the vapor pressure of the liquid. After cavitation has been established, the rate of flow through the venturis will remain constant as long as the critical pressure ratio is not exceeded. A typical characteristic pump curve appears on this page. It will be noted that by selecting the operating point sufficiently below the knee of the curve, variations in back pressure can be tolerated without an attendant variation in flow through the venturi. Through careful calibration, operating mixture ratio is predictable within 1%.

The principal of the cavitating venturi is likewise utilized in the open-loop control system. Having established the operating mixture ratio of the fuel and oxidizer pumps, the proper power level is set by sizing the gas-generator venturis to produce rated thrust. Thus, as long as the venturis are operated in the cavitating region and the gas-generator c^* remains constant, flow rate to the gas generator will remain constant despite minor variations in downstream pressure drop. Extensive testing determined the effect on turbine speed due to variations in parameters such as suction pressure, propellant temperature, and turbine back-pressure. Equations were developed to predict speed within $1^1/_2\%$.

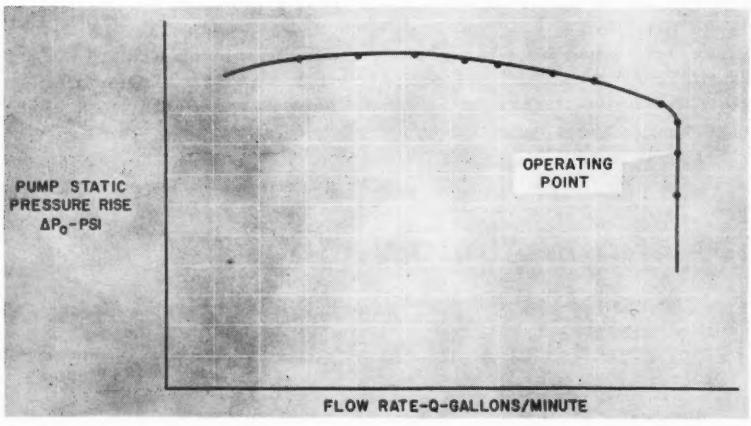
A combination of hysteresis of the spring-loaded oxidizer valve and pump deceleration time at low back pressure resulted in excessive oxidizer afterflow during the shutdown transient. For flight plans incorporating a dual start requirement, such a penalty in oxidizer dead weight is excessive. To correct this situation, a stored volume of gas, piloted by an explosive valve, pressurizes the dome side of the oxidizer valve, resulting in a significant saving of oxidizer afterflow. The pressurizing gas is vented off through a No. 70 orifice during the coast period to restart. This modification is strictly in keeping with the maximum reliability concept of not affecting the design of the basic component; the basic valve is unchanged and the added control is of minimum complexity and fail-safe.

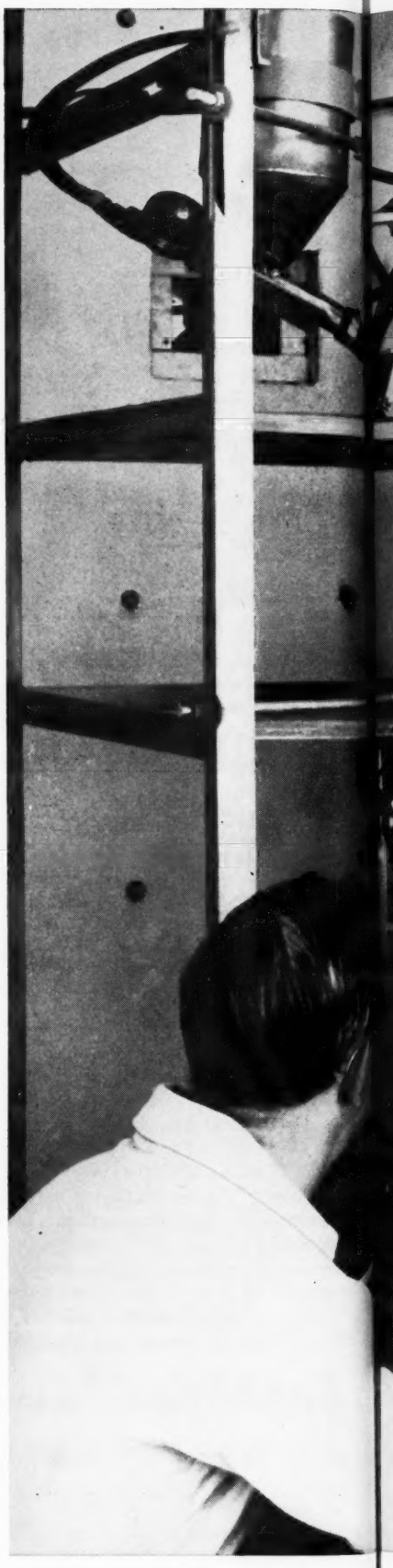
Agena Family Data

From an operating standpoint, the Agena Models 8048, 8081, and 8096 are similar, and therefore data from all three can be used to arrive at reliability figures. In ground tests, reliability has been 99.6% in 567 dual-cycle starts involving a total firing time of 33.756 sec. In 19 flights involving Agena, reliability has been 100%.

The Agena engine has demonstrated a unique capability for its storable propellant combination, inhibited red fuming nitric acid and unsymmetrical dimethylhydrazine. The engine has fired successfully after being stored in the drained and unflushed condition with an inert-gas suppression pressure. Experience indicates that the storage problems are even less severe with the system loaded. It is fair to say that the Agena engine and its propellant combination cannot be overlooked in the class of storable rockets for future missions. ♦♦

Typical Pump Characteristic Curve





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Design note

A Closed-Cycle System for Gas Bearings

By J. H. Laub and H. D. McGinness
JET PROPULSION LABORATORY, CALTECH, PASADENA, CALIF.

The support of sensing masses of inertial instruments by gas lubrication and flotation has considerable inherent advantages. The virtual elimination of starting friction and of drifts caused by anisoelastic effects and mass shifts is a typical example. If missions of short duration are involved, as is the case in missile or booster applications, the required supply of compressed gas can readily be stored in suitable containers in the vehicle. However, in missions of long duration, such as lunar or planetary explorations, the storage of expendable gas becomes impartical because of the size and weight of the container. A closed-cycle system in which the gas is recirculated then becomes mandatory.

The severe constraints on energy sources available in space vehicles are of prime importance in the selection of a regenerative-gas-supply system. Direct utilization of thermal energy, without conversion to electrical and mechanical power and its attendant low efficiency, is obviously preferable to electromechanical systems. For example, if an efficiency of 30% is assumed for motor-driven compressors or pumps and of 10% for thermoelectric cells converting solar radiation into electric power, an over-all efficiency of 3% can be attained. If a system employing thermal power is used for the recirculation pumping of a gas or vapor, however, solar radiation or thermal energy from a nuclear reactor can be applied and, by saving the conversion losses, the power requirement can be reduced very substantially.

These considerations have resulted in a study of the feasibility and performance characteristics of a thermally pumped closed-cycle vapor system for gas-lubricated bearings and gas-floated inertial instruments in space vehicles.

A regenerative system of this type consists of an evaporator in which a suitable fluid is vaporized and raised to the required operating pressure. A pressure regulator keeps the pressure at a set value and a superheater raises the temperature sufficiently above the dew point to avoid condensation at the temperature of the gas bearing. After passing through the bearing, the vapor is condensed and the condensate pumped back into the evaporator.

Freon Vapor System

The selection of a suitable fluid for a closed-cycle system is influenced by a number of considerations. The fluid must be inert with respect to the materials used in the construction of gas bearings and inertial sensors (steel, aluminum, etc.) and gasket materials such as neoprene. It should be nonexplosive, nonflammable, and of low toxicity. Its specific heat and heat of vaporization should be as low as possible to minimize the energy required to raise it to operating pressure. It should also be chemically very stable and have low viscosity, since the friction torque is proportional to the latter.

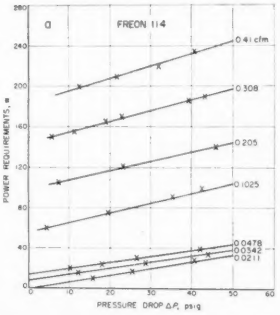
These specifications are satisfied by a number of the Freon compounds. The graph at below center shows the pressure-temperature relationship of various Freon compounds (as published by the DuPont Co.). It will be noted that the pressure of Freon-113, for example, can be increased from 0 to 50 psig by raising the temperature from 118 to 214 F. The temperature range can be shifted to suit various environmental conditions. For instance, using Freon-114 instead of Freon-113, the same pressure increase of 50 psig can be produced by raising the temperature from 38 to 122 F. A Freon system can thus readily be optimized with respect to ambient conditions, i.e., temperatures in the payload compartment and the solar radiation panel.

The gas consumption of an externally pressurized bearing depends on its design and, in particular, on the number and size of its orifices and the height of the gap. The supply pressure depends on the load-carrying capacity and stiffness required. A typical journal gas-bearing, to support the gimbal axis of a single-axis gyro, will consume approximately 0.7 cfm of air at 32 psig plenum pressure if rows of orifices are used as pressure regulators and approximately 0.15 cfm if slits serve the same purpose. A gas-floated spinning sphere which may be employed as a stable reference or as a momentum-transfer means for attitude control can be operated with a substantially lower flowrate, i.e., approximately 0.05 cfm, since it can be supported by four or six pressure pads with a single orifice each.

Experiments

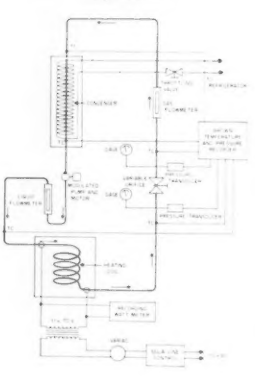
To determine the thermal power required within the range of the above flow rates and pressures, data were taken on an experimental closed-cycle system, diagrammed below left. A dome-shaped vessel is about half-filled with liquid Freon, into which a pancake-shaped Chromalox heater coil is immersed. The

Freon-114 Operating Characteristics

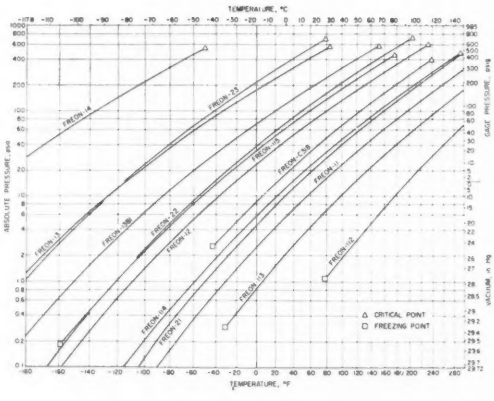


Pressure vs. thermal-pumping power

Test Equipment for Closed-Cycle Liquid-Gas System



P-T for Freon Compounds (DuPont)


TEMPERATURE, °C
ABSOLUTE PRESSURE, psia
GAGE PRESSURE, psig
VACUUM, in. Hg
FREON-14
FREON-22
FREON-C318
FREON-11
FREON-113
FREON-12
FREON-114
FREON-21
FREON-C316
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power input to the heater is controlled by a regulating transformer (Variac) and is measured by a wattmeter. The flowrate of the fluid in the vapor phase and in the liquid phase is measured by variable-orifice-type flowmeters. The temperature and pressure distribution in the system is determined by thermocouples (TC) and pressure transducers which are connected to a recording instrument. The gas bearing was simulated in the experiments by a regulating valve whose rate of flow and pressure drop could be adjusted within the required range. It was enclosed, together with the evaporator and gas flowmeter, in a wooden housing filled with vermiculite for better insulation. A graph on page 70 gives results of some of the experiments with Freon-114.

Energy Balance

The thermal power, E, required for the regenerative system diagrammed below can be written as follows: $E = E_1 + E_2 + E_3 + E_4$, where E_1 is the power required to raise the temperature of the liquid from the sump temperature in the condenser to the boiling temperature in the evaporator, E_2 is the power required for the enthalpy gain between the saturated liquid and the saturated vapor at operating pressure, E_3 is the power input for superheating, and E_4 is the total heat-power loss of the closed-cycle system to its surroundings.

The boiling temperature of a given Freon compound for a desired operating pressure can be read from the Freon chart. The increase in enthalpy, E_2, at this temperature for the transition from the liquid to the saturated vapor phase can be obtained from pressure-enthalpy diagrams which the DuPont Co. has published for various Freon products.

It can be shown that E is a linear function of mass flowrate, W (but not a linear function of the pressure). To arrive at an estimate of E, the heat loss E_4 is assumed to be proportional to the difference Δt_1 between the vapor temperature and ambient (room) temperature, that is, $E_4 = \alpha \Delta t_1$. The experiments showed α to be indeed constant within the range investigated and to equal 0.52, if Δt_1 is measured in degrees F. For calculating E_1, a sump temperature of 25 F was used. Since the experiments were carried out without superheating the Freon-114 vapor, E_4 in the energy-balance equation becomes zero.

Shown on page 70 are computed values for E for three flowrates—0.0478, 0.0342, and 0.0211 cfm, plotted as solid lines. The comparison with the measured power input, corrected to a room ambient temperature of 75 F, for these three flowrates (symbols) shows a degree of correlation which can be considered satisfactory in view of the limitations involved.

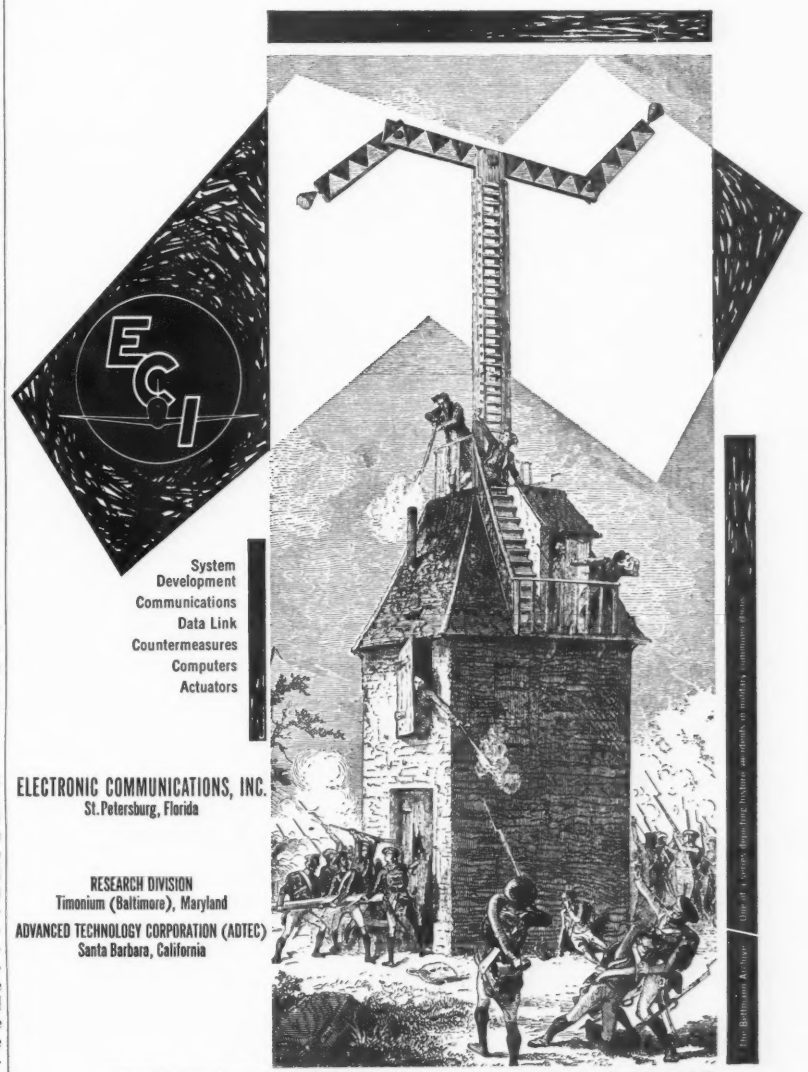
Conclusion

The conclusion can be drawn from this investigation that a closed-cycle system, using Freon or some other fluid with similar thermodynamic properties, is quite feasible for long space missions. The thermal pumping power can be obtained directly from solar radiation (in panels or concentrators) or from nuclear reactors, if and when available. Condensation of the fluid is accomplished by exposing it to the dark side of the spacecraft. The liquid is returned to the evaporator by a miniature mechanical pump or by capillary action. It can be shown that the pumping power for the small liquid flowrates involved is negligible. ♦♦

LONG RANGE INPUT / 1794

News of the recapture of Condé from the Austrians was sped to the French Revolutionary Convention at Paris in a matter of minutes via Claude Chappe's amazing télégraphe aérienne, or relay aerial telegraph, Sept. 1, 1794. A new era in rapid communications had begun.

Today, instantaneous and completely reliable Electronic Communications insure the immediate and continuous interchange of intelligence throughout the Free World. ECI is proud of its initiative and responsibilities in the design, development and manufacture of high precision electronic equipment to the critical specifications required in various aerospace and surface roles vital to our National Defense and to scientific achievement. An example is ALRI—Airborne Long Range Input—a program where ECI communications and data link equipment fill an integral and essential requirement in linking USAF's advanced early warning system to SAGE—our continental defense network.



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Amazing Motions

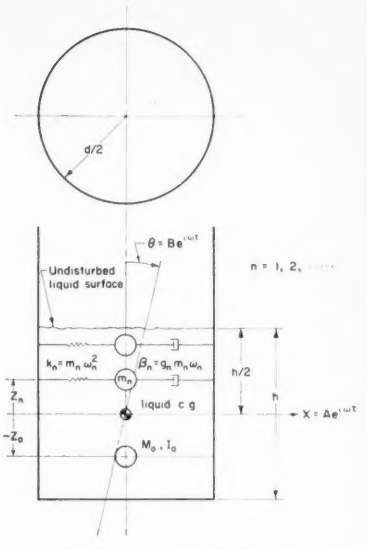
(CONTINUED FROM PAGE 37)

behavior for longitudinal excitation of the tank. A number of interesting phenomena have been observed under such conditions, including one in which small gas bubbles, caused by surface disturbances, form in the liquid near the bottom of the tank and, contrary to normal expectation, do not rise to the liquid surface but remain at or near the bottom. It has also been observed during vertical excitation of a cylindrical tank that the liquid free surface becomes unstable and generates a rather strong spray, shown on page 35.

Rotational Motions

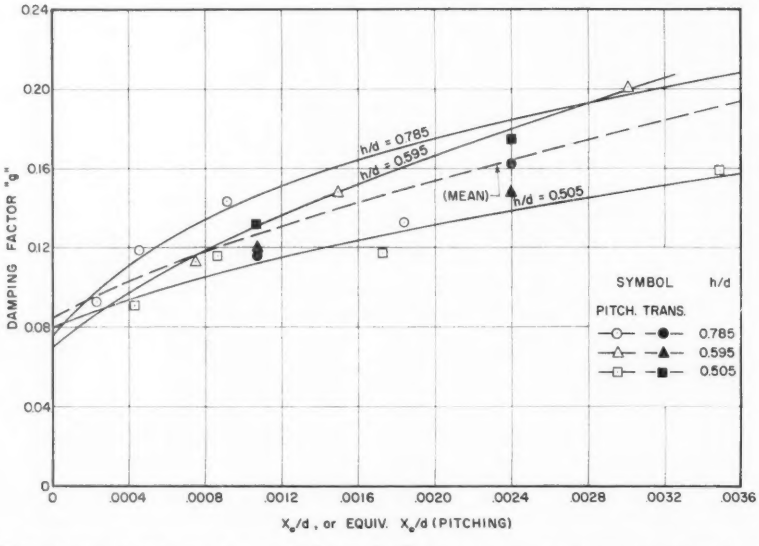
Liquid-propellant behavior that involves rotational motions about the tank longitudinal axis are of special interest because of the torque exerted on the tank, changes in inertial distributions, and reductions in flow rate during tank draining as a result of vortex formation. One interesting motion of this general type can be observed during translational excitation of a partially filled tank at frequencies near resonances of the free surface motions of the liquid (normal sloshing) and can best be described simply as an apparent "rotation" of the liquid about the vertical axis of symmetry of the tank, superimposed on the normal sloshing motion. The motion is even more complicated, as a type of "beating" also seems to exist: The normal first-mode sloshing first begins to transform itself into a rotational motion increasing in angular velocity in "say" the counterclockwise direction, which reaches a maximum and then decreases to essentially zero, and then reverses and increases in angular velocity in the clockwise direction, and so on alternately. The frequency of rotation is less than that of the surface wave motion, and therefore the liquid appears to undergo a vertical up-and-down motion as it rotates about the tank axis. The rotational frequency about this up and down axis is about the same as that of the wave motion. The liquid free surface, at least at relatively low excitation amplitudes, is essentially plane and it is the apparent rotation of this inclined plane about a vertical axis that we are attempting to describe.

Other interesting rotational-type motions occur when the tank itself rotates about its longitudinal axis with some prescribed angular velocity so that the liquid climbs up the side walls as a result of the centrifugal forces, and when vortex formation takes place as a result of liquid being drained from the tank. Vortexing is undesirable, of course, because of the consequent reduction in flow rate and pumping efficiency, particularly near burnout, where flow conditions are quite critical. The formation of a vortex during tank draining is very dependent upon the degree of initial rotation of the liquid. Fortunately, the growth of the rotational motion itself is largely suppressed by conventional baffling employed for suppression of normal sloshing; sloshing itself tends to break up the vortex as it forms; and finally it is relatively simple to provide small but effective anti-vortexing baffles near or at the drain outlet.

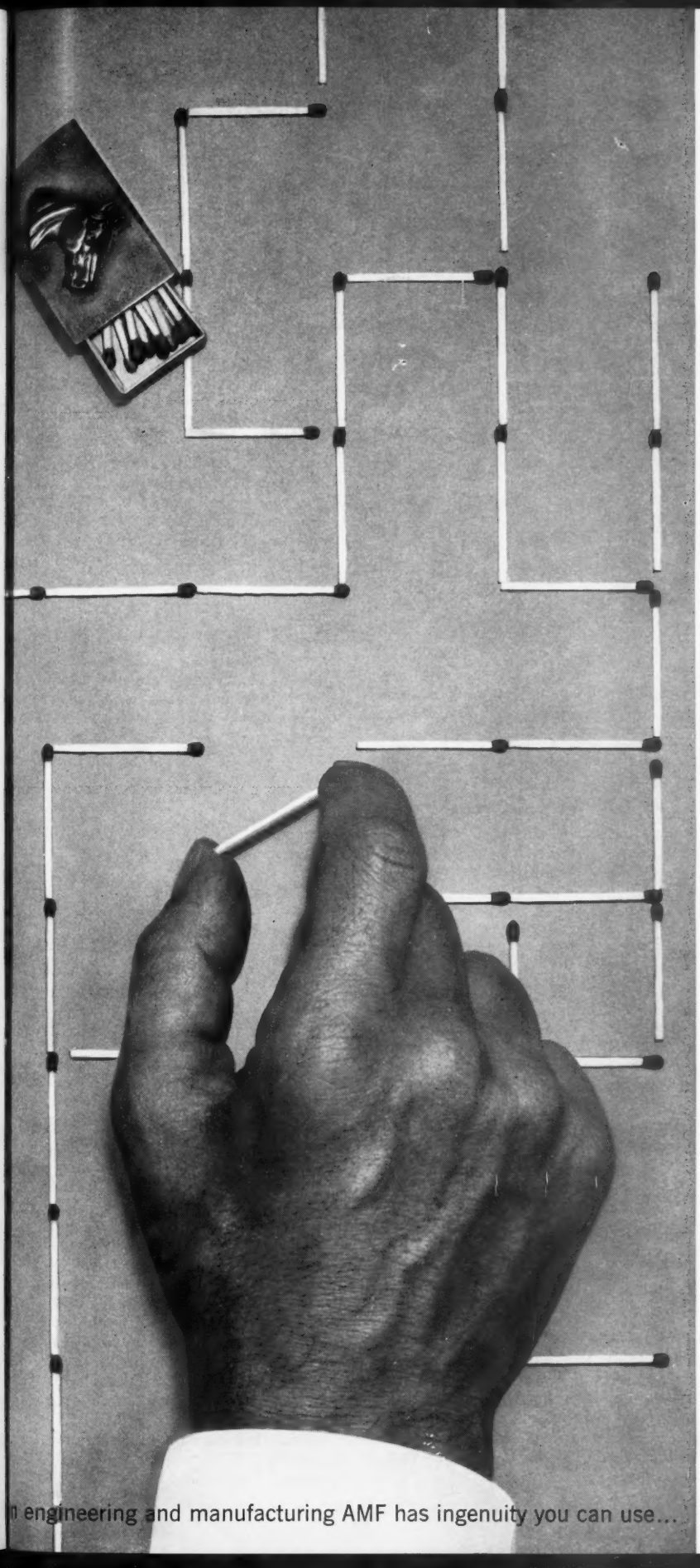


An equivalent mechanical system employed for evaluation of sloshing effects. The sloshing liquid is replaced by a single fixed rigid mass and a series of spring-mass-dashpot elements located at varying distances from the liquid center of gravity. These mechanical elements will provide a total force and moment on the tank equivalent to that produced by the sloshing liquid.

Certain flight profiles or engine restarts from coasting or orbital flight may result in a reversal in direction of net acceleration. In such cases the liquid may undergo large displacement motions and, in effect, move from one end of the tank to the other and thus impact upon the opposing tank bulkhead. Once again, mathematical treatment or analysis is virtually impossible, and recourse is made to dynamically similar laboratory tests in which both the model liquid and the acceleration time history must be properly scaled. High-speed motion-picture films of such dynamically similar models show that as the net acceleration reverses the liquid first flows away from the free surface along the side walls; this is followed by a breaking up of the free surface into streamers or jets which progress rapidly down the tank and are followed closely by the remaining bulk of the liquid. Finally, the entire flow becomes utterly and hopelessly confused as the front running portions and streamers of liquid begin to rebound from the impacted end of the tank.



Plot of damping factor for conical ring baffle suppressors in terms of dimensionless excitation amplitude, X_0/d, at one value of effective Reynolds number. The damping provided by these baffles is very nearly the same for both translational and pitching motions of the tank. The damping decreases with increasing Reynolds number.



He designed a new interchange for radio traffic

This AMF engineer, part of an AMF-U.S. Army team, solved the problem of traffic delays and personal danger in manual re-connection of jumpers when interchanging R.F. transmitters and antennas.

His solution is a push-button-operated, coaxial crossbar switching system, using vacuum switches for circuit selection. A typical system consists of 4 transmitter inputs, 7 antenna outputs plus a dummy load, in a 4 x 8 matrix that can be mounted in a 19″ rack. It can be controlled locally or remotely over any type of communication network having a bandwidth of at least 200 cycles.

AMF's coaxial crossbar switching system provides 100% flexibility in circuit path selection and accommodates power levels as high as 500,000 watts and frequencies up to 30 megacycles. It allows 100% utilization of all transmitting equipment. Stubs are automatically eliminated.

To insure fail-safe operation, power is required for the vacuum switches *only* during change of condition. Selection rate: 1 per second. Operating transmitters are safety-interlocked to insure a load. There are no hazards from open wires or inadvertent application of power to dead-lined antennas.

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The behavior of liquids under conditions of reduced or zero gravity offers an entirely new host of phenomena of great interest. Not only are the liquid motions and configurational changes of interest, but problems concerned with positioning of the liquid mass within the tank for engine restart operations are of great practical importance. Practical means of accomplishing such positioning may well take the form of low-level thrust applied briefly by compressed gas or solid-propellant motors, or expulsion bladders. It is interesting to observe that, during reduced-gravity conditions, wetting liquids (conventional fuel, water, etc.) will tend to flow along the tank walls, while nonwetting liquids (such as mercury, for example) will tend to form globs which float free inside of the tank. The behavior of boiling liquids under low-gravity conditions, indicated in the photos on this page, is also of great importance.

This summary of liquid-propellant dynamic behavior is certainly not complete; but it should serve to demonstrate the variety of phenomena that can occur, and to point out that several different theoretical and laboratory techniques must be employed to insure an adequate understanding, and the acquisition of sufficient detailed knowledge, to enable practical methods for ameliorating adverse dynamic effects of liquid motion.

Editor: Eighteen selected references on this important subject are available on request from Astronautics, *ARS Headquarters, 500 5th Ave., New York 36, N.Y.* ♦♦

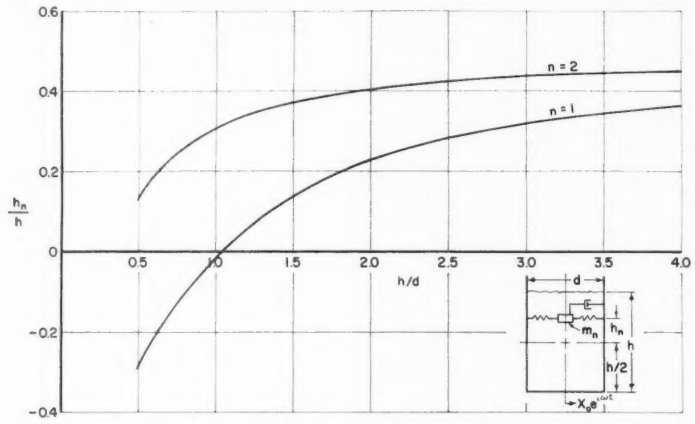


Diagram showing location of spring-mass-dashpot elements in the equivalent mechanical system; $n = 1$ and $n = 2$ correspond to the first two such elements.

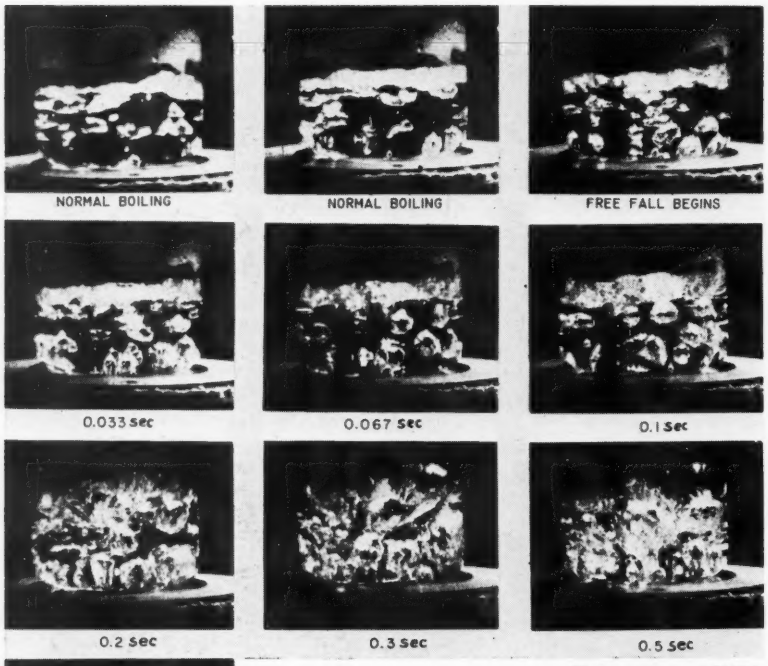


Photo courtesy of NASA

Pool boiling from the bottom of a cylindrical tank during free fall to simulate zero gravity. At the beginning of free fall, the bubbles move upward through the liquid as in normal boiling, but then remain suspended in the liquid as the free fall continues. Increasing quantities of vapor are contained within the liquid during the free fall, or reduced-gravity, condition.

NBS Forms Two New Advisory Committees

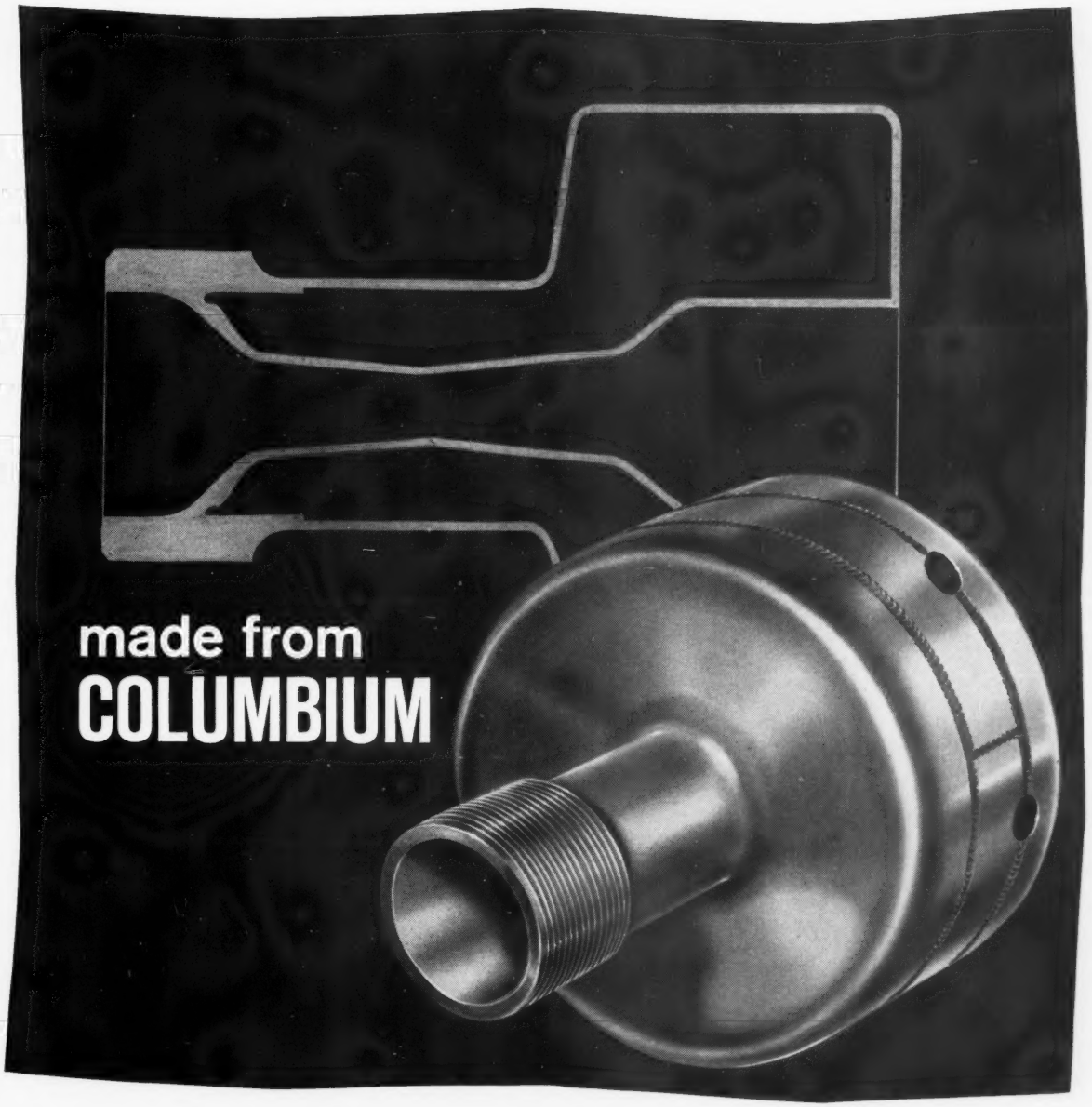
The National Bureau of Standards, responding to the need for more and better services in critical areas, such as gage blocks, has formed two new advisory committees, one on Calibration and Measurement Services and one on Engineering and Related Standards.

Douglas, STL Making "Beyond Saturn" Studies

NASA's Marshall Space Flight Center recently awarded Douglas Aircraft and Space Technology Laboratories six-month contracts for $30,125 and $48,505, respectively, to study the most economical space vehicle for payload requirements beyond Project Saturn. Vehicles having takeoff thrusts of 3-, 9-, and 12-million lb will be studied in terms of Saturn and Atlas-Centaur. Propulsion candidates will be Rocketdyne's H-1 or F-1 engines in any of several first-stage combinations and LRR-119 and J-2 lox-hydrogen engines in upper stages.

A Catch in Life Testing

A National Bureau of Standards study of sampling procedures that assume an exponential failure law, when actually the law is the Weibull distribution, has found that these widely used statistical techniques are very sensitive to departures from initial assumptions. For further information, see "The Robustness of Life-testing Procedures Derived from the Exponential Distribution," by Zelen and Dannemiller, to be published in "Technometrics" this month.



Mere conventional knowledge about metals does not account for the successful welding, machining and spinning that this structure has undergone. The Budd Company has solved many of the critical problems of fabricating a reliable structure from columbium—as well as from other promising new metals such as zirconium, hafnium, beryllium, tantalum and molybdenum.

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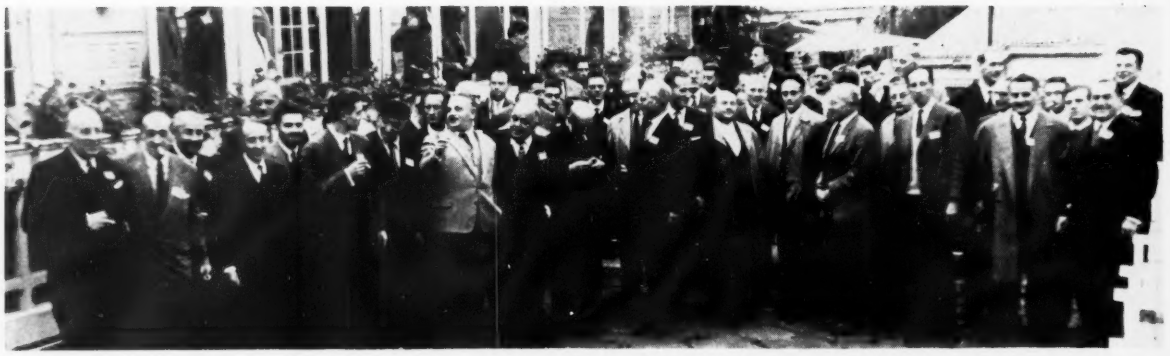
International scene

By Andrew G. Haley

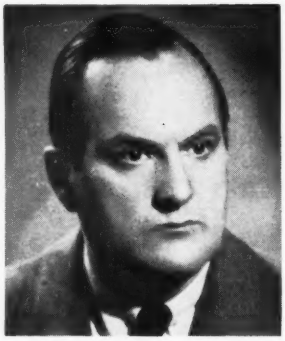


Well-known faces in international astronautics appear in this gathering of the Societe Francaise d'Astronautique, holding a meeting at Louveciennes, near Paris, last November. ARS Director A. K. Oppenheim attended the meeting (see Letter from Paris in the January 1961 *Astronautics*).

OUTSTANDING among the many excellent jurists on the international scene in the field of space law is Michel Smirnoff of Yugoslavia, recently elected chairman of the Executive Committee of the International Institute of Space Law at the XIth International Congress of the International Astronautical Federation at Stockholm in August 1960. Dr. Smirnoff, who is 49 years old, married and has a 12-year-old daughter, resides in Belgrade, Yugoslavia, where he is occupied with the affairs of the Foreign Trade Research Institute which he helped found in 1956.

Very active in IAF affairs, Dr. Smirnoff has participated in the Colloquia on the Law of Outer Space which have been held in connection with IAF Congresses in Amsterdam (1958), London (1959), and Stockholm (1960), and has served as a member of the Committee of Six established at London in 1959 for the purpose of organizing the International Institute of Space Law. His excellent work on that committee contributed greatly to the successful creation of the Institute.

Dr. Smirnoff's impressive background well-equips him for his efforts on behalf of international cooperation in space activities. Born in St. Petersburg, Russia, on July 10, 1911, Dr. Smirnoff moved with his parents in 1919 to Serbia, part of the newly formed State of Yugoslavia. His education was obtained in Belgrade and in 1933 he graduated from the Law School of the Univ. of Belgrade. Specializing in international air law, Dr. Smirnoff also studied at the Institut des Hautes Etudes Internationales at Paris, receiving a diploma from that institution in 1935. He was awarded his degree of Doctor of Laws in 1936 by a jury composed of such noted jurists as Professors De Lapradelle, Ripert, and Scelle. His doctoral thesis was written on the subject of the activities and organization of CITEJA.



Smirnoff

During his law career, Dr. Smirnoff has served in the Yugoslav Ministry of Civil Aviation (1937–1941), the Ministry of Foreign Commerce (1945–1950), the Yugoslav Federal Chamber of Commerce (1950–1952), the Air Transport Commission (1953), and the Yugoslav Planning Commission. As a Flight Lieutenant in the Yugoslav Air Force, Dr. Smirnoff fought in several battles in World War II until captured by German forces on April 16, 1941. From the date of his capture until April 1945 when he was liberated near Dresden by units of the Soviet Army, Dr. Smirnoff saw the inside of no less than eleven prisoner-of-war camps.

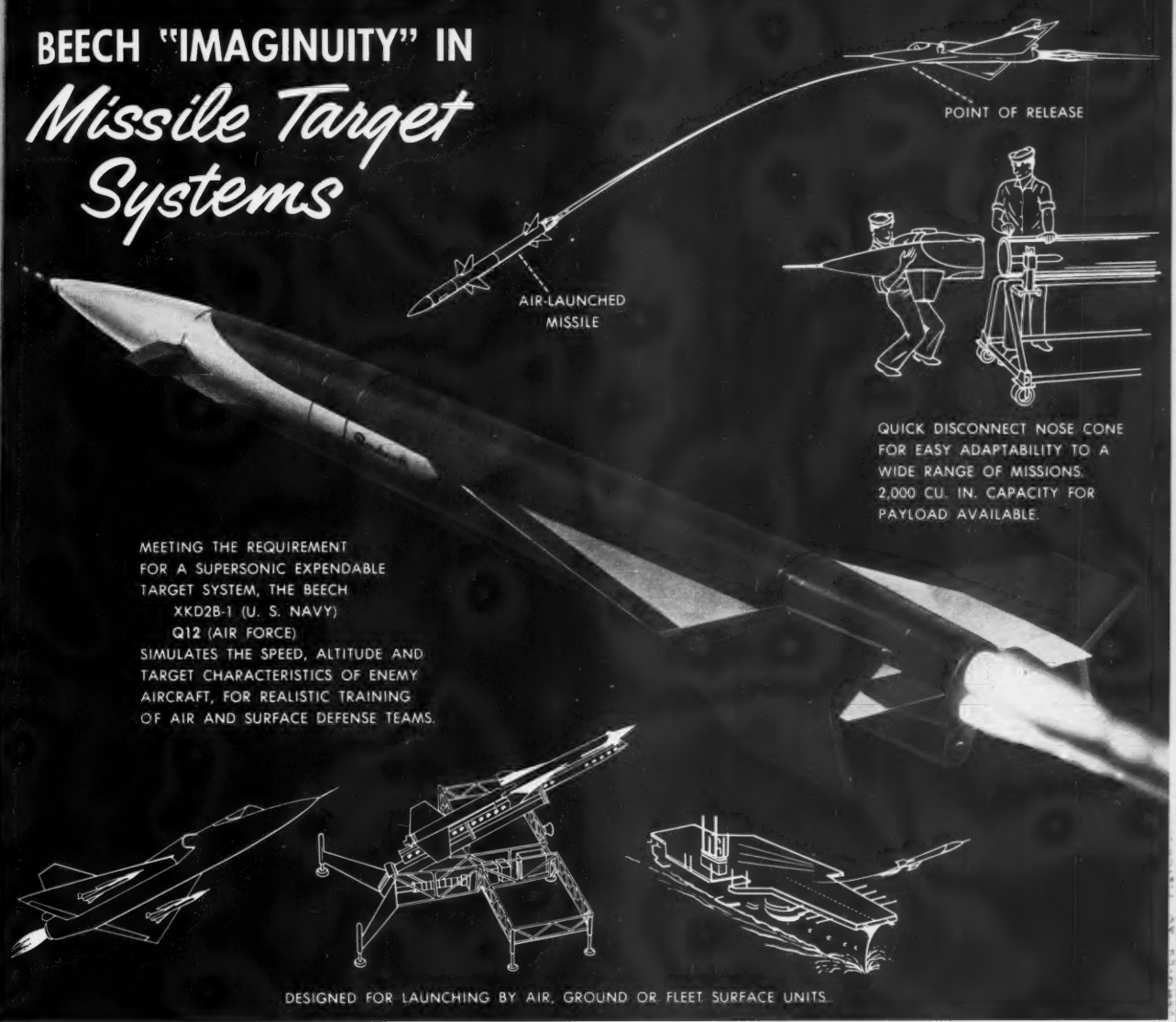
Well known for his many writings on subjects in the fields of air law, space law, and international law, Dr. Smirnoff is a frequent contributor to such journals as *La Revue Generale de l'Air*, *Revue Francaise de Droit Aerien*, and *Zeitschrift fur Luftrecht und Weltraumrecht* as well as to many Yugoslav law reviews.

* * *

COSPAR Vice-President Richard W. Porter of GE, in his remarks at the Argentinian Symposium on Space Research in Buenos Aires (February, page 16), suggested that one unique opportunity open to experimenters from the Latin-American countries lies in the fact that there is no land-based equatorial launching site for small sounding rockets. Dr. Porter noted that there is a considerable need for such a launching site and added that, if Latin-American scientists either in one country or cooperatively in several countries were to establish a site, it would be of considerable interest to their U.S. colleagues.

Dr. Porter also suggested that Latin-American scientists might also explore the possibility of participating in the COSPAR-sponsored International Rocket Intervals, especially since there exists a need for data obtained by means of rocket firings in many different parts of the Southern Hemisphere. ♦♦

BEECH "IMAGINUITY" IN *Missile Target Systems*


POINT OF RELEASE
AIR-LAUNCHED MISSILE
QUICK DISCONNECT NOSE CONE FOR EASY ADAPTABILITY TO A WIDE RANGE OF MISSIONS. 2,000 CU. IN. CAPACITY FOR PAYLOAD AVAILABLE.
MEETING THE REQUIREMENT FOR A SUPERSONIC EXPENDABLE TARGET SYSTEM, THE BEECH XKD2B-1 (U. S. NAVY) Q12 (AIR FORCE) SIMULATES THE SPEED, ALTITUDE AND TARGET CHARACTERISTICS OF ENEMY AIRCRAFT, FOR REALISTIC TRAINING OF AIR AND SURFACE DEFENSE TEAMS.
DESIGNED FOR LAUNCHING BY AIR, GROUND OR FLEET SURFACE UNITS.

Beech XKD2B-1/Q12: Winner of Navy/Air Force design competition . . .

Mach 2 target system for realistic training born of Beech cryogenic + airframe experience

Designed to simulate the speed, altitude and target characteristics of enemy aircraft, the Beech XKD2B-1/Q12 makes possible effective testing of advanced weapons systems and provides realistic training—at low cost—of air, ground and fleet defense units. Into its development has gone more than 6 years of Beech experience in cryogenics, plus over 27 years of airframe know-how. With its pre-programmed guidance system, it operates at altitudes from 1,000 to 70,000 feet and at speeds up to Mach 2. Adaptable for use with Nike, Terrier and Talos launchers, the target system has promising potential for economical development as a missile system. It can carry a substantial payload, to fulfill a wide range of future missions.

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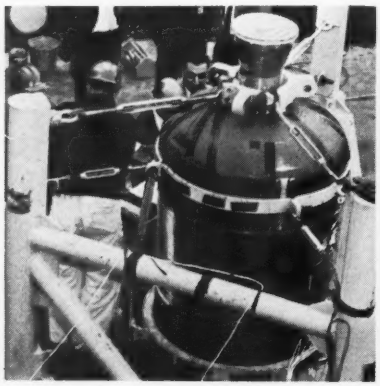
Conical Segmented Motor Passes Trials

Less than six months after its formal beginning, NASA's program for establishing the feasibility of giant solid-propellant rockets passed a milestone—the successful static firing of a 15,000-lb-thrust conical segmented motor by United Technology Corp., contractor investigating the building-block concept of solids for the space agency (see August 1960 *Astronautics*, page 26). The demonstration motor, the first of three now tested under UTC's present contract with NASA, contained three segments each weighing about $^1/_2$ ton, including UTC-developed high-energy propellant.

According to UTC executive vice-president B. L. Adelman, the test demonstrated the techniques of economically fabricating conically shaped motor segments and of insulating segment joints. The most important single factor in the test, he said, was the successful performance of the mechanical joint used to hold segments together. The joint, a clevis similar to a tongue and groove with shear pin, has been developed by UTC in cooperation with Pratt & Whitney Aircraft, also a Div. of United Aircraft.



Left, last-minute prepartions on the $1^1/_2$-ton conical segmented demonstration motor, rated at 15,000-lb thrust; right, the firing, which lasted nearly a minute. The three UTC demonstration motors have now been tested successfully.

Man in Space

(CONTINUED FROM PAGE 39)

capsule. In the first place, we need to devise ways of keeping our astronaut alive and in a good physiological state. To accomplish this, we have to find ways of supplying him with adequate nutrition, water, and atmosphere; we have to protect him from the hazards of acceleration, weightlessness, and radiation; we have to find ways of disposing of his physiological wastes; and we have to provide him with devices which will enable him to make effective use of his sensory and motor capability.

All of the studies in these areas make up the biological side of space science, and the end product will be the construction of a biocapsule. In addition to keeping the astronaut alive, we will also have to find ways of maintaining his mental capability in a state suitable for carrying out his mission. This would include the development of useful skills and resourcefulness, the creation of a psychological environment which would serve to maximize his efficiency, and the maintenance of a state of properly motivated, alert rationality. This area of study adds up to psychological research.

Unfortunately, a great deal of the research now going on or being planned, although called "psychological research," is really physiological investigation. The result of this error is likely to be that the useful biological information uncovered may go unnoticed because of the incorrect label on it, while the psychological data desired will not be forthcoming.

What underlies this dilemma?

There are numerous professions which have come to be identified with studies of human behavior. The main ones are psychiatry (a branch of medicine), psychology, sociology, and anthropology. Members of these professions, all of which fall under the umbrella of "behavioral scientists," have very different kinds of training but may often be found engaged in very similar studies. Psychiatry and anthropology are basically biological sciences having major sociological overtones, while psychology and sociology are social sciences possessing some biological overtones. The natural sciences have sometimes been called "hard" sciences to distinguish them from the sociological studies, which are often called "soft" sciences. The "hardness" of the former is alleged to be descriptive of their preoccupation with mathematics and quantitation, whereas the "softness" of the latter is said to be a reflection of the more qualitative nature of their approaches.

Unfortunately, these "soft" sciences have been massively opposed by the natural scientists, to the extent that there exist very few examples of good working relationships between the two. The nature of the opposition has been such that few natural scientists have familiarized themselves with the subject matter of the behavioral sciences, and vice versa. Psychiatry is the one specialty which can most appropriately bridge the gap between the two, since it is, ideally, a blend of the two, and the complete psychiatrist is familiar with both languages. Actually, however, only a few psychiatrists have attained this completeness; and instead of their being accepted by both groups, they have more often been rejected by both.

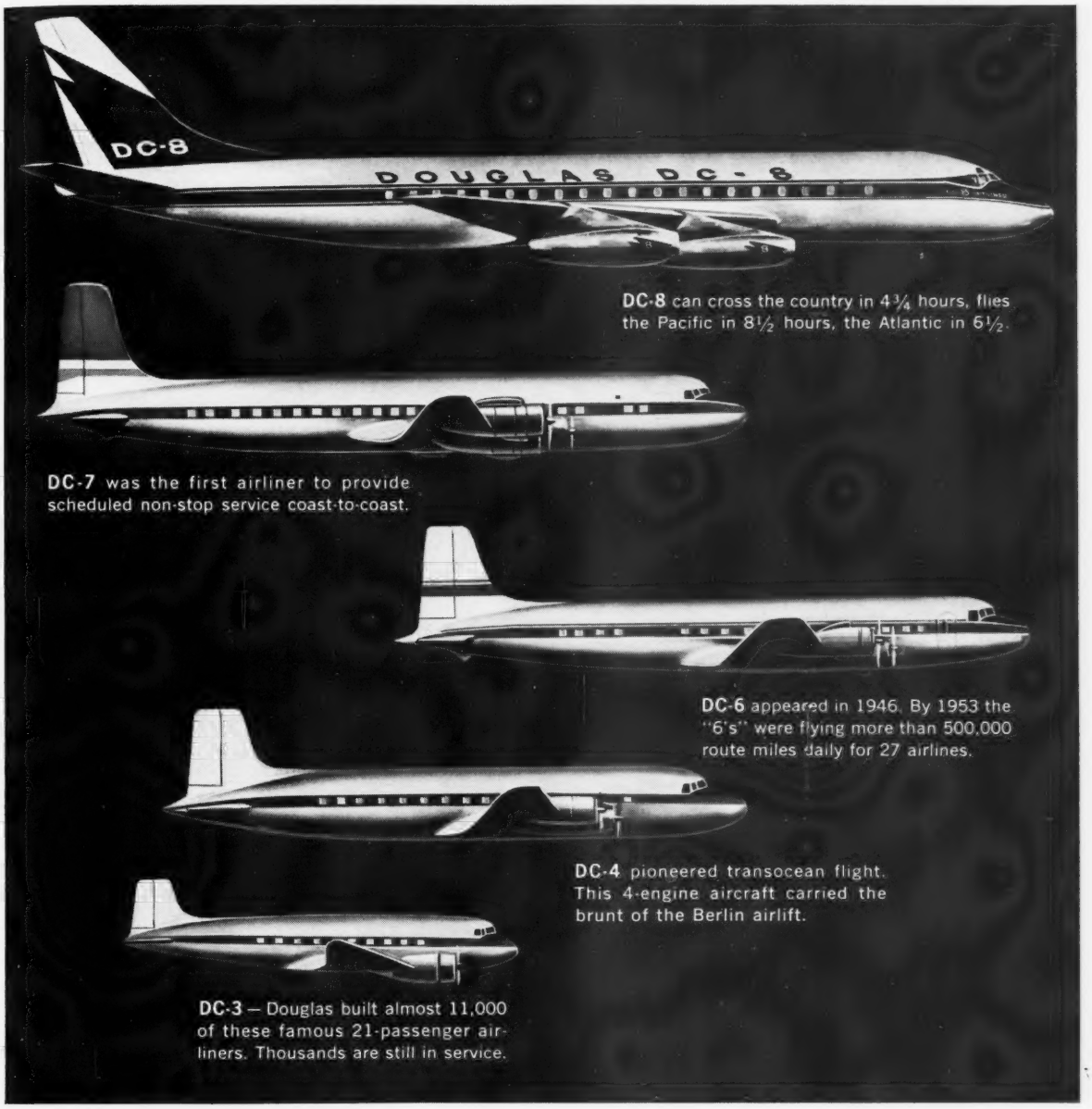
The type of thinking which tends to characterize the biological and physical scientists is a mechanistic one, in which the process of thinking operates mathematically. Quantities, measurements, forces, cause-and-effect, equalities, rates, etc. are the data which make up their thinking processes. The use to which this is put is primarily that of making predictions. The element of qualitative judgment is not consciously important in the process, and natural phenomena are studied in order to make use of them in the service of man.

Inclusive Thinking

In contrast, the thinking which characterizes the behavioral scientist is evaluative. The data used in his process include variables, interrelationships, chance, motivation, growth, experience, fantasy, etc.—all of which bear little resemblance to the thinking of the other group. The behavioral scientist most often is concerned about finding ways of changing "bad" behavior to "good," and this requires an extremely flexible use of qualitative judgments.

The field of space research has been, until now, completely dominated by the thinking of the engineer and physicist; and of all scientists they are the most mechanistic in their thinking. Engineering dominance has been a result of the fact that missile development has been almost solely one of hardware production. It has only been during the past two years that space science has come to include the

One of a series of advertisements showing the breadth of Douglas experience being devoted to commercial, military and space-exploration projects.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DC-8 can cross the country in 4¾ hours, flies the Pacific in 8½ hours, the Atlantic in 6½.
DC-7 was the first airliner to provide scheduled non-stop service coast-to-coast.
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How narrow the oceans have become! How small the world! And how quickly the shrinking has occurred!

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A Contender for Moon Exploration?

Electromechanical manipulating systems, mobile and equipped with television "eyes" for allowing remote operation, are showing up in many space-vehicle design studies. Hughes Aircraft's new Mobot II gives an idea of the accomplished engineering that has gone into robots. Here Mobot II, directed by the operator, who views arms through outrigger TV cameras, pours liquid from one flask to another.

subject of man in space. To achieve man in space, a primary emphasis has been the creating of a biocapsule in which the astronaut might survive. Very late in this development, and almost as an afterthought, the psychological environment in which the astronaut will have to function in space has come under consideration.

Because of the dominance of engineering thinking, not to mention administrative control, plus the general antipathy among the physical scientists for the "soft" sciences, a self-defeating trend has appeared. The engineers have come to recognize the necessity of looking into psychological problems and have sought the services of the behavioral sciences. However, they have required of behavioral scientists the same kind of mechanistic thinking which characterizes their approach to hardware development; quantitative laboratory experiments are demanded of the same order carried on in physics. It happens that among the so-called behavioral scientists there is a large number of people whose outlook and training are as mechanistic as the engineers'. They have become engaged in research which, though called "psychological," is really biological, and thus they have become acceptable to the mechanical thinkers.

The reason for this mislabeling is not entirely fraudulent, for these people are simply taking advantage of the fact that most of the research money intended for psychological or social research is controlled by people unsympathetic to these studies. Those in control of the money are more likely to recognize the worth of physiological than behavioral studies, even though the former often goes under the name of the latter.

There follows a breakdown of 160 research projects supported by one of the military services in 1958. This group of projects comprises the total research effort in the area labeled "Psychological Investigation." It will be noted that nearly all the categories consist of physiological studies. The one called "learning studies," and perhaps the one called "sensory deprivation studies," might qualify as genuine psychological investigation.

Category of Project	% of Total
Measurement of hearing	40
Vision studies	41
Measurement of skin sense	4
Learning studies	4
Autonomic responses	4
Neuroanatomy	2
Electroencephalography	1
Motor responses	1
Sensory deprivation studies	1
Unclassified	1

There are large numbers of neurologists, for example, who are called psychiatrists, and many statisticians who call themselves sociologists, plus many physiologists who pass as psychologists, not to mention the several "cultural" anthropologists who appear to be "physical" anthropologists. Because these mechanistically oriented professionals are both numerous and highly subsidized and also speak the same kind of language as the engineer, they are the ones which are most likely accepted as allies by the physical scientists. As a result, true psychological or social research is rarely found in those areas where it is most needed; that is, in the areas where there is a maximum emphasis on machines and a minimum of attention to man.

Aviation, in the past, has suffered to a considerable extent from this type of misapplication of knowledge. The psychological aspects of aircraft instrumentation, traffic control, navigation, etc. have been largely in the hands of physiologists who have been called psychologists. As a result, the data they produce are physiological rather than psychological, although no one in the field seems to realize it. One of the consequences of the failure to realize the difference between the two studies has been the failure to differentiate between *visual acuity* and *paying attention*. This is a very fundamental distinction in the operation of aircraft. The ability of man to adjust to difficult situations has compensated for some of the errors made in this connection, and this has helped to hide the errors.

First Flight in Balance

The amount of daring and the amount of investment which we will be able and willing to afford in pursuit of our man-in-space program is likely to hinge on the success of our first experimental flights. This success will depend equally upon how well we develop three independent, though interrelated, lines of investigation. These can be conveniently classified as hardware, the biological environment, and the psychological situation. Failure to give adequate recognition to any one is likely to doom the experiment to failure. It is the last of the three which is most likely going to be overlooked because of the common illusion that biology is psychology. ♦♦

NASA Sponsors New Research On Metastable Propellants

NASA revived contract work on high-energy metastable chemical compounds late last year in a modest way, and with the new budget may be in a position to amplify interesting work in this field.

LOW ALTITUDE...†
LIGHT TO HEAVY LOAD
TRANSPORT WITH
HOT AIR BALLOONS

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- CAN BE TOWED BY HELICOPTER
- SUITED FOR SHIP LAUNCH
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- MANNED OR REMOTE CONTROL
- REUSABLE

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* 30000	40	5200	430	3.5	130
250000	86	20000	3125	16.4	120
1000000	140	50000	12500	41.0	120
3000000	200	104000	37500	83.0	120

*BUILT AND FLOWN REPEATEDLY

† to approximately 15,000 feet.

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WRITE FOR A DESCRIPTION OF RAVEN BALLOONS, INFLATABLE STRUCTURES, URETHANE FOAM SPRAY SYSTEMS, AND CONTROL INSTRUMENTATION.

Scout Propulsion

(CONTINUED FROM PAGE 31)

which would allow for propellant contraction; and subsequently a motor was successfully fired at 30 F with no evidence of trouble.

In addition to furnishing performance data, a jet-vane development program was conducted simultaneously with these tests, and the behavior of the entire rear transition section was evaluated. A fifth firing at 30 F was conducted under the Air Force Scout program and was also completely successful. The first Algol was delivered five months after being ordered, with the static testing continuing after initial motor delivery. To date, five Algol motors have been flown, all successfully.

A comparison of nominal performance and flight behavior of the Algol motor can be seen in the pressure-time history shown at the bottom here The shaded band is the one-sigma spread from the nominal pressure and burning time, and the solid line is the actual ST-1 Algol pressure-time history. Although pressure does not give a true indication of total impulse variation, it illustrates that the value of this parameter in flight was within the range obtained in static tests.

The motor chosen for the second stage essentially uses the proved hardware of the XM-20 and XM-33 Jatos. These units, successfully flown in many NASA and AF programs, are an outgrowth of the booster program for the Sergeant missile. Tooling and production techniques were readily available. However, a decision was made to shift to a new, relatively untried high-performance propellant being developed as part of the Pershing and Minuteman programs. In addition to use for the Scout, the motor was required for the NASA "Little Joe" vehicle, and development costs were shared by both of these programs. The final propellant, while similar to that used for Pershing, was tailored to meet the requirements of the Little Joe and Scout programs. A new nozzle was designed to withstand the increased flame temperature.

The early Castor development was plagued with a high reject rate because of propellant cracking during postcuring operations and because of voids. A study of processing variables led to the establishment of closed controls on polymer lots and processing procedure. These resulted in better and more closely controlled physical properties and essentially eliminated the reject problem.

Static-Testing Results

Five Castor motors were static-tested in the propellant and nozzle development program. The nozzle exit cone burned off during the first motor static tested, although ballistic results were excellent. After subsequent nozzle redesign, there were no more nozzle failures, and the remaining four development shots were all successful. Six preflight rating tests were also performed. These demonstrated that the motor could be successfully fired at initial temperatures between 20 and 110 F and that the motor could survive temperature cycling and rough handling. All 11 motor firings were successful, demonstrating that inspection procedures were more than adequate.

Castor delivery was accomplished within 10 months after the contract was let to Thiokol. To date, 10 motors have been fired as part of the Little Joe, Scout, Langley re-entry research, and Blue Scout programs. Five of these 10 motors were boosted. All performed as expected, with no malfunctions of any kind.

Castor thrust-time history obtained from telemetered data is given here below. The shaded band indicates one standard deviation from the nominal thrust and burning time, as obtained from the development and test program. The agreement between flight and static-test data is good and is within the accuracy obtainable from flight data.

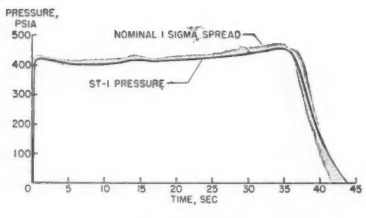
Scout's third stage was an entirely new development. It was felt that a filament-wound glass-fiber plastic case could be developed to meet the tight requirements on low case weight and minimum misalignment with considerably less cost, testing, and effort than could one of metal construction. ABL was chosen because of their experience and success with the X-248. It was decided that the Antares (X-254) would be essentially a scaled-up X-248 and that it would utilize the same propellant design, construction, and production technology.

The case development presented no significant problems. This phase of the program was straightforward and handled in an exemplary manner from the start. The initial attempts produced excellent cases which met all the requirements. This program was a tribute to the excellent technology that has been developed in filament-wound glass-fiber rocket-motor-case design and manufacture.

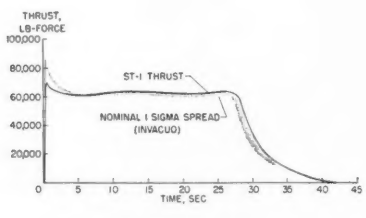
A total of 20 Antares motors were static-tested, of which six early ones failed. It was determined that these failures were caused by poor bonding at the propellant-to-case interface and poor resonance-paddle design and attachment. Changes in design materials and manufacturing techniques eliminated this source of trouble. Then, three firings were conducted at near vacuum conditions in the AEDC Tullahoma facility. These showed a weakness in nozzle design. Pressure buildup of gases trapped or generated between the nozzle ablative liner and the outer glass-fiber plastic-nozzle structure caused the liner to buckle inward. This behavior could introduce excessive thrust misalignment and had to be eliminated.

A straightforward engineering solution, which proved successful, was suggested by ABL. Hundreds of small holes were drilled through the outer nozzle shell to a depth where they penetrated to the interface, thus vent-

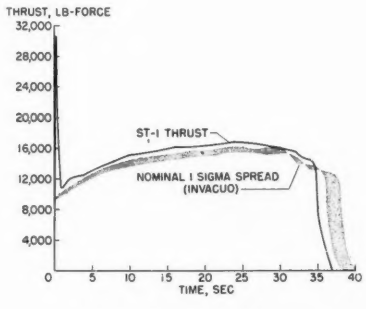
Scout Motor Performance in First Flight Test



Algol First Stage



Castor Second Stage



Antares Third Stage

ing the gases to the atmosphere and eliminating the pressure buildup which caused buckling. This modification proved successful in a subsequent AEDC static test. In addition, the static tests produced a motor qualified for firing between 50 and 100 F. Even with the development difficulties, the first Antares was delivered within 15 months after being ordered.

The Antares X-254, like the X-248, borders on unstable burning which is suppressed by a resonance paddle. Normally, the motor is still relatively rough burning, and the induced vibrational levels are erratic. The test program furnished an adequate source of information, however, on the anticipated frequencies and amplitudes of vibratory loads. This information was fed into the vehicle design and test program. The two successful flights of the Scout vehicle proved that adequate provisions had been made to handle these Antares vibratory loads. Instrumentation to measure vibration amplitudes and frequencies confirmed the results obtained in static tests. An unusual result of this unstable burning showed up in the flight tests, and this will be discussed in a moment.

Antares Performance

Antares performance data are shown on page 82. The one-sigma spread from the nominal values of the Antares, the shaded band, are for a temperature of 77 F. The flight-performance thrust from acceleration, the solid line, has not been corrected for the actual motor temperature, and the deviation is probably due to the fact that the ambient temperature for several days preceding launch exceeded 90 F. Also, at times the motor was in an enclosed environment during assembly and checkout. The high initial peak is probably due to loads imposed during separation, and possibly due to amplification of the transient loads because of vehicle structure and accelerometer mounting.

The fourth stage, named Altair, is the X-248 motor developed for the Vanguard program and successfully flown in many orbital, space, and sounding-rocket missions by the AF and NASA. The principal difference between the Scout Altair and the X-248 is in the attachment design. For Altair, attachment studs are embedded in a doubler that is integrally wound with the case. The development program and results obtained in other flights are well documented and will not be covered here. In almost all instances, where the motor was allowed to perform, results were satisfactory. The Altair can be delivered within six months from the time of ordering.

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have been successfully flown. These two flights were programmed as high-altitude probes and were heavily instrumented to monitor all the important aspects of performance.

During the first Scout launching, the fourth stage was purposely prevented from firing because of a malfunction in tracking instrumentation. This gave an erroneous indication that the vehicle was out of the prescribed safety limits of its trajectory. For the second Scout firing, the motor functioned properly and data on its performance are available but not completely reduced.

The first flight was terminated after third-stage burnout because of a peculiar combination of circumstances which indicated that the vehicle was off course. Subsequent analysis showed that the behavior indicated by instrumentation was physically impossible. It was determined that the radar was tracking on a side lobe; and, when the return signal became weak enough, the radar suddenly shifted to the main lobe, giving an abrupt indication of change of course.

Telemetered data showed that a large rolling torque was induced at the onset of rough burning in the third stage. The exact manner in which rough burning causes torque generation is not known, but is being studied. As torques of this magnitude were not anticipated, the roll-control system was not able to handle them. But when the motor ceased burning, the control system again was able to maintain roll control. The problem was eliminated by providing larger roll-control jets in the second flight and insuring that the radar was tracking on main lobe. In the second flight the torque was again present at the onset of rough burning. This time, however, the larger roll jets were able to maintain orientation, and the second flight was a complete success.

As has been shown, motor performance of each stage was within acceptable limits. The final proof of the over-all propulsion-system behavior lay in the ability to predict an accurate schedule of velocities imparted by each stage and the ability of the entire system to meet these velocity schedules. Results of the first Scout (ST-1) are presented here above. The calculated results, shown by the solid line, represent the best prediction based on all available propulsion and vehicle-system inputs. The dotted line with circular symbols represents flight data obtained by differentiation of FPS-16 radar data. The agreement between the two curves is well within the accuracy of the techniques used for performance prediction and measurement.

Results of the flight of the second Scout (ST-2) are also shown on this page. The results are similar to those obtained on the first flight, and show that agreement between predicted and measured values are good. The performance measured in the second flight meets the requirements for an orbital mission.

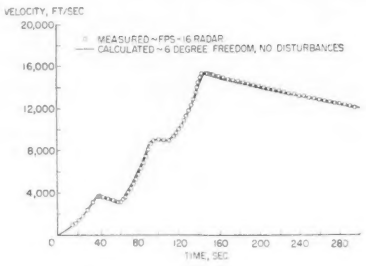
In both flights, except for the unanticipated torque, the propulsion systems did not impose any stress on the vehicle system or components which exceeded design capability. This includes motor misalignment, which was considerably less than control-system design for three stages.

The Scout propulsion approach has demonstrated that unsophisticated solid-propellant rockets can be combined to give a relatively high-performance space research vehicle.

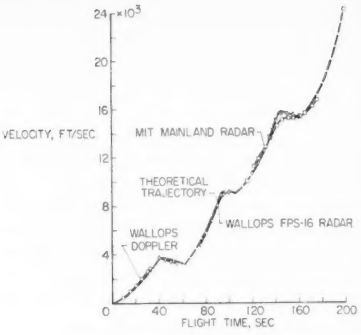
The use of existing hardware developed for other programs, in combination with a single new rocket design, which was based on current technology, has resulted in a reduction of cost, time, and development necessary to make a complete, reliable propulsion system. In addition, the Scout system was available in ample time to meet the launch schedule.

The members of the rocket industry participating in the Scout program, by their exemplary performance in developing, producing, and delivering solid-propellant rockets having carefully controlled performance and alignment, demonstrated that the industry is reaching a high degree of maturity. Their delivery of flight rounds after a minimum number of successful static developmental firings exhibited an exceptional degree of confidence and a high level of technical skill and experience. ♦♦

Scout Flight-Test Performance

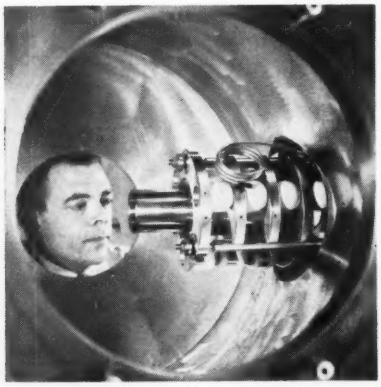


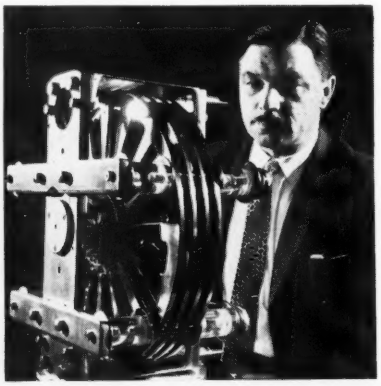
First Vehicle (ST-1)



Second Vehicle (ST-2)

Space Engine's New Look





Interesting principals in the Goodrich-High Voltage Astronautics Inc. program to develop and build a demonstration ion engine and associated electrostatic generator for the Air Force: Left, an experimental duoplasmatron in vacuum test tank; right, electrostatic generator. GHVA experiments are based mainly on bombardment ion sources, particularly the duoplasmatron arc source originated by M. Von Ardenne, but also include work with colloids. Since 1959, the company has been operating an experimental engine using argon or mercury as propellant.

LR-115 Engine

(CONTINUED FROM PAGE 27)

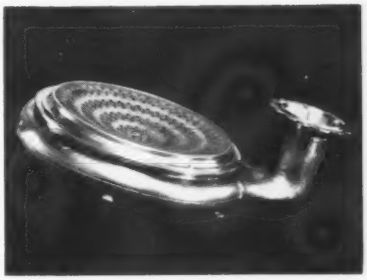
gen-gas cooling. Aside from precluding the frailties of an oil lubrication system, the high-temperature gradient between a necessarily warm oil system and the −423 F hydrogen pump impeller is avoided. The elimination of this temperature gradient, coupled with the low turbine-inlet temperature made possible by the hydrogen regenerative cycle, minimizes the temperature differential in the turbopump and allows the complete system to be housed in a compact assembly of aluminum castings.

The nozzle-expansion ratio of 40 was chosen as a compromise between engine weight and specific impulse. This relatively high-expansion ratio led to the selection of a "pass and a half" design for the propellant cooling flow to maintain reasonable coolant velocities throughout the thrust-chamber length. This design requires that the full and half-length tubes be interleaved at that axial station in the chamber where the long tube reaches its maximum diameter. The detail of the required tube sections are shown on page 27. The complete assembly is furnace-brazed, after fitting of the thrust-chamber tubes, manifolds, and bands on a mandrel. During the brazing operation, the assembly is rotated on its axis to provide uniform brazing-alloy coverage.

A schematic cross section of the LR-115 propellant injector is shown on page 27. The injector is a concentric-jet type with the central liquid-oxygen stream at each injection point surrounded by an annular stream of hydrogen gas. The central bulkhead, which separates the two propellants in the injector and incorporates the oxygen jets, is machined from a single forging. The photo at right shows an injector which has been fired 22 times for a total of 28 min.

Another feature of the LR-115 design is that the flexible sections commonly employed in engine plumbing to allow minor misalignment have been eliminated. With reasonable dimensional tolerances, it has been possible to use rigid plumbing throughout the engine. Because of the low-temperature service and large number of thermal cycles involved, rubber and plastic seals have been avoided in the design. Metallic seals developed for liquid-hydrogen service have proved to be leaktight after repeated thermal cycles and long-time storage.

LR-115 Injector After 22 Firings



To provide for multiple restarts in space, a high-energy electrical spark system was chosen for engine ignition. Most of the components in this system were taken directly from the equipment already developed for the J57 jet engine. A single exciter system, which is vehicle mounted, provides the energy for the spark plug in the Centaur installation. This insures simultaneous lighting of the two engines and tends to reduce the tolerance of impulse difference on a start-up which improves vehicle controllability.

These components and their design features are representative of the philosophy applied to the design of the

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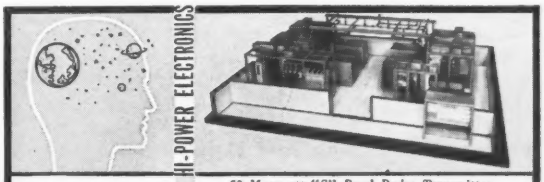

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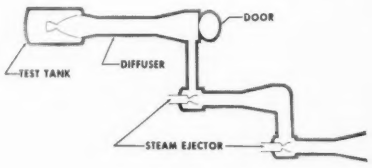
LR-115 engine. The objective has been to simplify the engine design wherever possible, thus contributing directly to the over-all vehicle system reliability.

The test stands used in the LR-115 development include four horizontal engine mounting pads and one vertical stand. The vertical stand is used for testing two engines simultaneously in combination with the propellant supply system for the vehicle itself. The component test complex has 20 individual test stands. Approximately 2500 test hours have been accumulated in component testing since the LR-115 engine development was initiated in October 1958. This work included testing of individual fuel and oxidizer pumps, the turbine, the gears, and the control components. Over 500 hr of testing were accomplished on various bearing configurations alone. This development yielded a design which has demonstrated better than 25 hr of useable bearing life under simulated turbopump operating conditions. Where possible, all parts of the engine have been rigorously tested as components prior to being committed to complete engine test.

The LR-115 development has made use of over 10-million gallons of liquid hydrogen in tests since 1955. The first complete experimental LR-115 engine was fired in July 1959, nine months after the design was initiated.

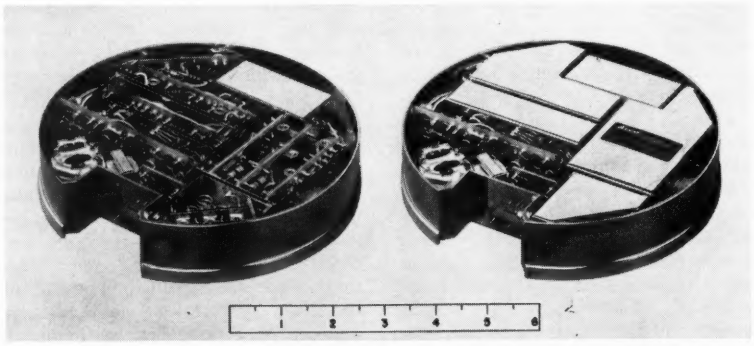
The equipment shown schematically here below has been used for all engine testing to simulate space

Schematic of Engine Test Stand



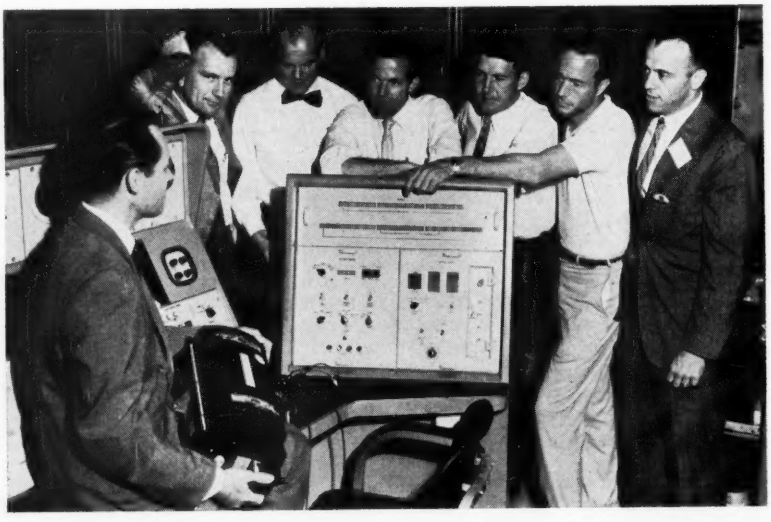
starting and running conditions. The engine is mounted on a thrust bed inside an alitude tank, which is aspirated by a two-stage steam ejector during the starting period. As the engine starts, a lightweight door is blown open at the end of the diffuser section. During steady-state running, the diffuser provides the pressure necessary to maintain full-flow conditions in the 40:1 area-ratio nozzle. Since the starting propellant flow is sufficient to choke the thrust chamber throat at the pressure level maintained by the steam ejectors, space conditions are completely simulated over the complete operating cycle. Firing durations of $5^1/_2$ min, which is the limit of propellant tank capacity, have been accomplished on these test stands.

In the testing to date on the single-position stands, the LR-115 engine has met or exceeded all performance requirements. A program to simulate the Centaur vehicle system is now underway in the vertical test stand, in which the flight-vehicle propellant supply system is tested with a dual-engine installation. Initial cold-flow tests have been completed, and hot-firing tests will begin in the near future. The LR-115 engine nears the time of active participation in our space programs. ♦♦



Avco Receiver Ready for NASA Satellites

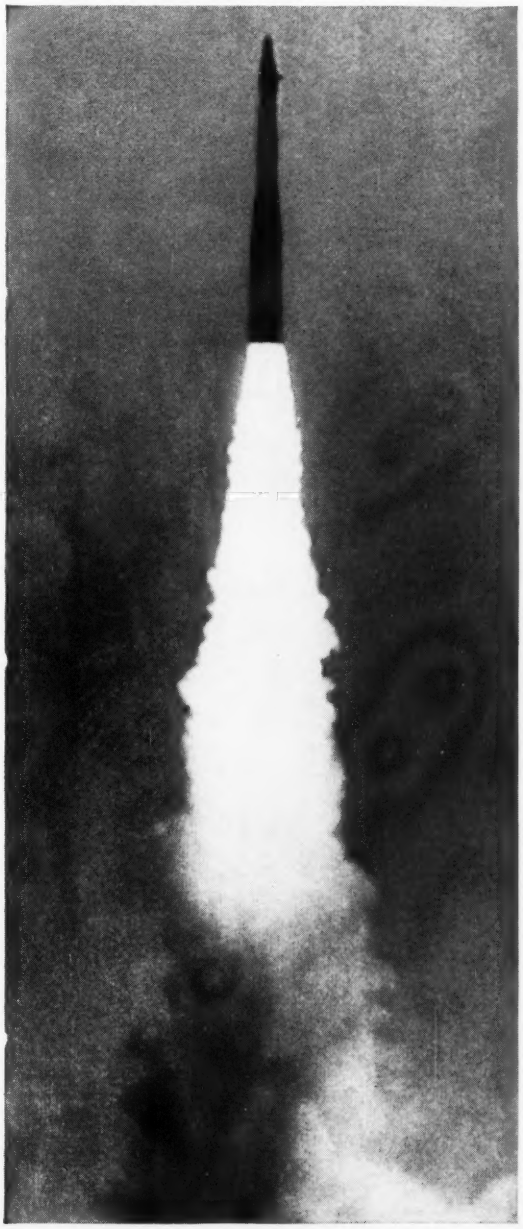
This miniaturized 1.5-lb receiver, developed by Avco's Electronics and Ordnance Div., features a 2-lb decoder, responsive to seven ground commands, that sets into play various electronic equipment in a payload. Its standby operation draws approximately 0.1 w; full interrogating power runs less than a watt. Designed to withstand high vibration and shock levels, the unit will be used in several NASA satellites.



Getting Ready

Astronauts (from left) D. K. Slayton, J. H. Glenn, L. G. Cooper, W. M. Schirra, M. S. Carpenter, and A. B. Shepard —among a party of 42 from NASA, STL, and the Air Force—get briefed on Atlas radio-command guidance as used in Project Mercury during a two-day readiness demonstration conducted at AMR by GE's Defense Systems Dept. and Burroughs Corp.

MINUTEMAN



Reliable power for peace at reasonable price, U.S. Air Force Minuteman which will be America's first ICBM with solid rocket motors successfully met its objectives in its initial full scale flight down the Atlantic Missile Range. First stage motor of the three stage Minuteman is designed and produced by Thiokol Chemical Corporation. During early test phases, Thiokol motors performed so superbly the original schedule of preliminary firings was cut to less than half, greatly accelerating the entire Minuteman development program. Through Thiokol engineered reliability, the nation's power to deter war is moving up while anticipated costs come down.

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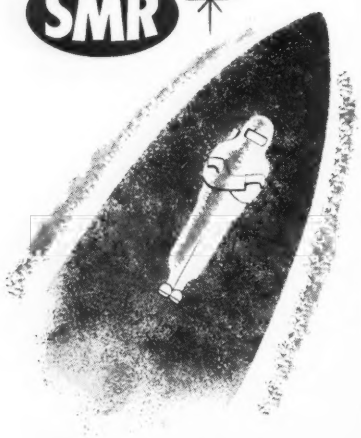

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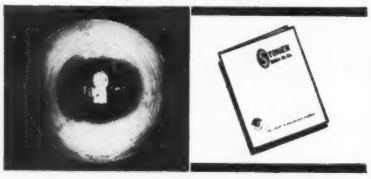
Photo of Rocket Chamber courtesy of Aerojet-General Corporation



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Laser Breakthrough Scored

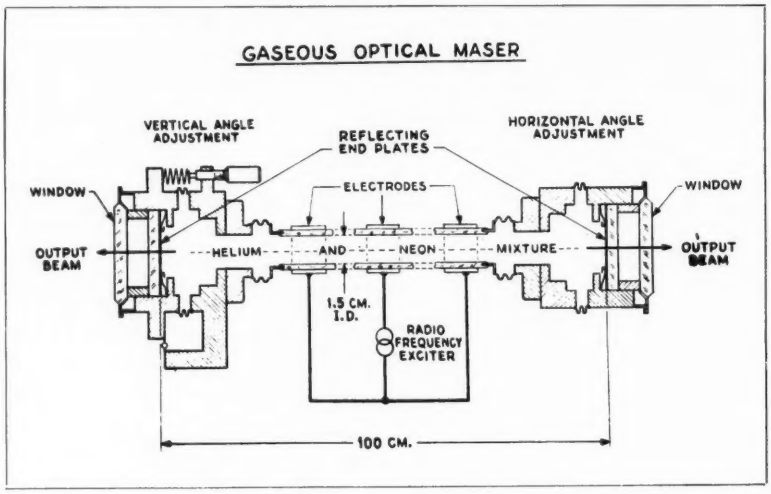
A continuously operating gaseous optical maser that runs on a few tens of watts, roughly like a fluorescent tube, and produces a light beam having an output of about $^1/_{100}$ watt and an angular spread less than 1 min of arc—this was the notable achievement presented to the astronautics community by Bell Telephone Laboratories scientists Ali Javan, W. R. Bennett Jr., and D. R. Herriott the first of last month, in conjunction with a formal letter report appearing that day in "Physical Review Letters."

Based on theoretical work by Dr. Javan, this laser employs helium metastable carriers to excite neon and produce ultrapure continuous emission at any of several wavelengths in the near-infrared. Its classic simplicity opens the way for extensive experimentation in gaseous-discharge physics, space communications, commercial communications, high-temperature chemistry, and other fields.

Space applications of lasers have been widely discussed recently. Less notice has been given to the optical maser's potential for semiconductor technology and for analyzing atomic structure. For instance, the Bell laser allows, for the first time, observing difference-signals of radio frequencies between two optical lines, and its beam lines are thousands of times sharper than the best spectroscopic lines available in the optical region. On the other hand, focused down to the micromillimeter area, its beam can produce very high temperatures causing local chemical reactions with functional electronic properties in semiconductors.

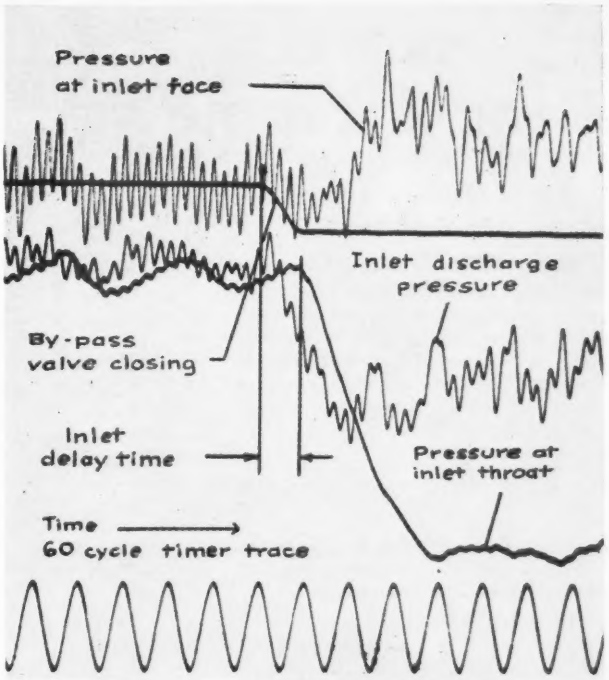
C. H. Townes, who invented the maser in 1955, appeared publicly to congratulate the Bell scientists on their history-making achievement, and in particular the incisive analyses of Dr. Javan, which led to a working device in one clean stroke.

Dr. Ali Javan of Bell Telephone Laboratories inspects the working model of the laser he proposed. Below, a diagram of the laser proper, which operates on low power and can be built fairly easily for experimental work.



In research...

A Model 906 Honeywell Visicorder wrote this record of pressure fluctuations... "buzz"... for engineers at the NASA Lewis Flight-Propulsion Laboratory in Cleveland. "Buzz" is an unsteady variation in the pressure and airflow characteristics of a supersonic aircraft or missile inlet. These Visicorder studies defined the buzz-free operating limits of the inlet, and provided the designers with structural load information in case the inlet were inadvertently caused to operate on buzz during flight. This load information is vital, for inlet buzz can result in fluctuating structural loads of the order of 1000 psf... loads which could cause structural failure of the inlet and loss of the airplane. Visicorder records such as this have played an important role in the design of inlet control systems.

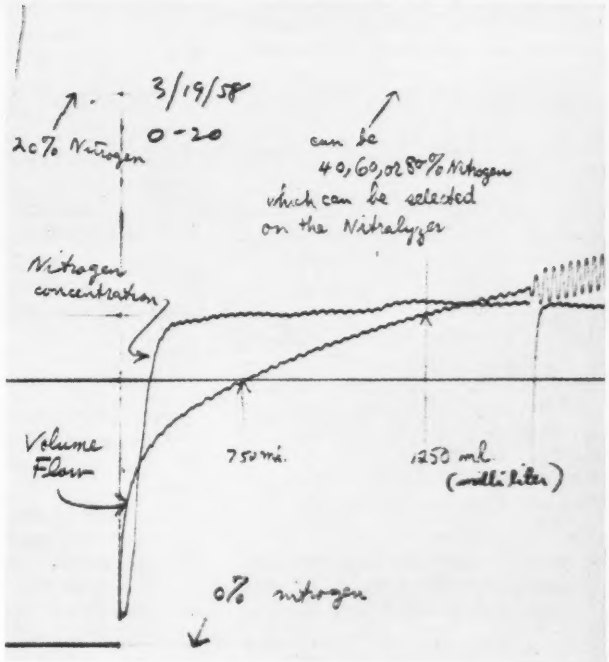


these are records of leadership

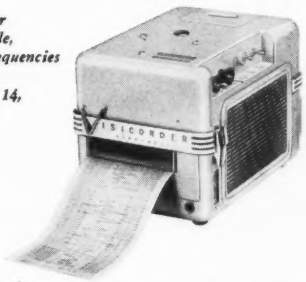
In medicine...

This directly-recorded Visicorder chart has told the scientists of the U. S. Public Health Service Occupational Health Program an important story about uneven alveolar ventilation in the human lung during a single breath of oxygen. In these lung function tests, the Visicorder measured anatomic dead space and abnormalities in the distribution of inspired gas in the alveoli of the lungs. The subject, under test, inhaled 100% oxygen to dilute nitrogen in the lungs. The Visicorder recorded the volume and the nitrogen percent of the exhalation. In these and in hundreds of other scientific and industrial applications, Visicorders are bringing about new advances in product design, computing, control, rocketry, nucleonics and production.

For information on applying the unlimited usefulness of the Visicorder to your specific problems, phone your nearest Honeywell Industrial Sales Office.



Visicorder records 2/3 actual size.



The Honeywell Visicorder provides instantly-readable, high-sensitivity data at frequencies from DC to 5000 CPS. There are models with 8, 14, or 36-channel capacities.

Honeywell

Industrial Products Group

Reference Data: Write for specifications on Visicorders 906B, 1108 and 1012.

Minneapolis-Honeywell Regulator Co., Industrial Products Group, Heiland Division, 5200 E. Evans Ave., Denver 22, Colorado

People in the news

APPOINTMENTS

George Gerard, associate director of NYU's College of Enginering Research Div., and chairman of the ARS Structures and Materials technical committee, has been appointed staff director for academic and research development of NYU's University Valley, Sterling Forest, N.Y.

Frank B. Estabrook has been appointed chief of the physics section at JPL.

Peter H. Wyckoff has been upped to assistant director of physics research at Armour Research Foundation.

Lawrence J. Giacoletto has been appointed a professor in the Dept. of Electrical Engineering and the Div. of Engineering Research within the College of Engineering at Michigan State Univ.

Robert L. Hirsch has been named assistant to vice president **Richard D. Geckler** of Aerojet-General's Solid Rocket Plant, Sacramento.

Herbert C. McKee has been appointed assistant director of the Dept. of Chemistry and Chemical Engineering of Southwest Research Institute.

Douglas D. Ordahl has been named manager of United Technology Corp.'s Propellant Development Branch.

Harold Lyons has joined Electro-Optical Systems, Inc., as a vice-president, and will manage the company's newly formed Quantum Electronics Div. **Milton J. Allen** and **Frank A. Ludwig** have been named manager and associate manager, respectively, of the Chemical Research Dept. **L. Edward Godycki** has joined the technical staff as a senior research physicist, Solid State Div.

David S. Lewis has been appointed executive vice-president, McDonnell Aircraft, and Vice-President **John F. Aldridge Jr.** takes charge of advanced product planning. **Sanford N. McDonnell** becomes F4H vice-president-general manager and **Chester V. Braun,** Quail general manager.

Robert D. Calvert has been appointed general manager of Lear, Inc.'s Electro-Mechanical Div.

Max Lehrer, former assistant staff director of the Senate Committee on Aeronautical and Space Sciences, has been appointed director of defense business development of the RCA Defense Electronic Products Div., Washington, D.C.

Lt. Col. Gordon L. Harris has been promoted to Army asistant chief of information.

Col. Murray A. Bywater, USAF, has been appointed Site Activation Task Force Commander for the AF Titan II ballistic-missile site at McConnell AFB, Wichita, Kan.

Burton F. Miller, vice-president and director, advanced technical planning, Thompson Ramo Wooldridge, has been reappointed to the AF Scientific Advisory Board.

Lovell Lawrence Jr., ARS fellow member, has been named executive engineer of Chrysler Corp.'s Advanced Projects Organization.

Arthur G. Norris has been transferred to Vitro Engineering Co.'s N.Y. headquarters as manager of the proposals department, and **Joseph Mazia** succeeds Norris as manager of the Washington office.

Louis R. Farin becomes programs and contracts manager, Bulova Research & Development Laboratories, Inc.

Frederick W. Hesse, vice-president of Space Technology Laboratories, will also serve as director of the company's newly formed STL Products Div., which will commercially market scientific and technical devices developed from STL research in space and missile technology.

Henry S. Black has been named general manager of the new Data Recorders Div., a combination of the DataTape and Electro Mechanical Instrument divisions, at Consolidated Electrodynamics Corp.

C. E. Fitton Jr. will head Thiokol Chemical's Advance Concept Analysis Group and **James L. Carnes** becomes manager, advanced planning, both at Rocket Operations Center, Ogden, Utah. **Kenneth P. Rice** becomes manager, Seattle operations located at Boeing Airplane Co.

John L. Altekruse will head Goodyear Aircraft's new Aerospace Dept.

Bert F. Prentiss has been promoted to chief inspector, quality and reliability, Mishawaka Div., Bendix Corp.

H. P. Roberts has been named general manager, Siegler Corp.'s Space Systems Technology Group.

Frank C. Bresk has been elected president of Monterey (Calif.) Research Laboratory, Inc., a new subsidiary of Research, Inc., of Minnesota.

H. F. Goelzer has been named manager of the new Plans & Programs Dept., Pomona Div., Marquardt Corp.

Burl H. Ervin has been appointed director of applications engineering, Systems Dept., Nortronics, a division of Northrop Corp. **Shigeo Okubo** has been named manager, gyro platforms, Precision Products Dept. in the division. **Phillip N. Buford** has joined Page Communications Engineers, Inc., a subsidiary, as senior staff engineer, R&D Directorate.

Warren N. Arnquist has been appointed assistant to the director of advanced research, Schuyler Kleinhans, at Douglas Aircraft.

Maj. Gen. Raymond C. Maude, AF-Ret., has been appointed director of field operations, Philco Corp.'s Government and Industrial Group.

Ralph F. Gow has been elected president of Norton Co. and **John Jeppson,** executive vice-president.

Harold V. Hance has joined the Systems Research Center of Lockheed Electronics Co. and will serve as both

(CONTINUED ON PAGE 92)

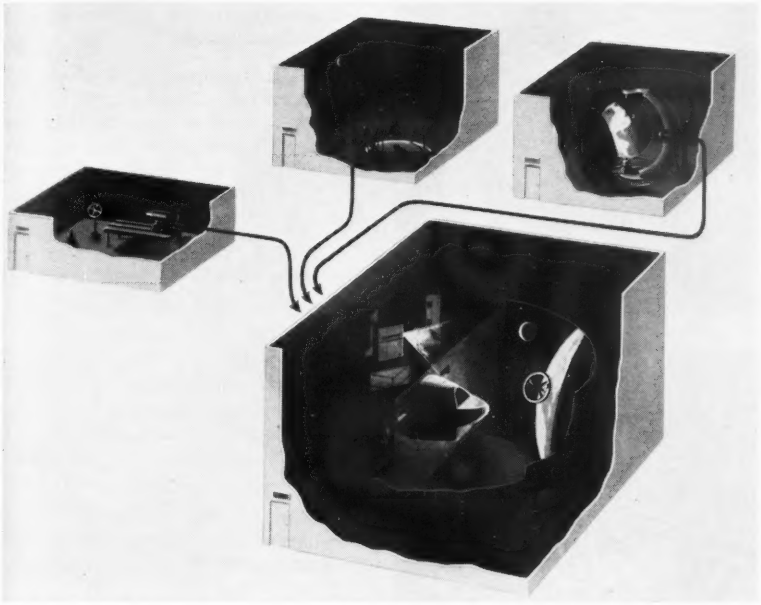
Ordahl

Lyons

Calvert

Lawrence Jr.

Bell Visual Simulator for Space-Flight Training



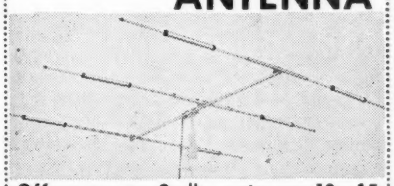
Depiction of Bell Aerosystem's concept of a visual simulator for space-flight training.

Bell Aerosystems has received an AF (Aerospace Medical Div.) contract to determine whether a combination of closed-circuit TV and models representing the earth, moon, and planets can be employed in astronaut training through a visual similator, like the one depicted here.

In this Bell proposal, a theater (lower center) houses the space-vehicle mockup. Directional screens, which receive images from separate projectors, are in the view field of each space-vehicle window. Image generation studios (upper right to left) supply high-resolution TV pictures to the projectors. The visual simulation is a composite of images produced by TV cameras viewing an earth globe (upper right), a celestial array (upper center), and a space-station model (upper left). All three cameras and models are driven synchronously to move in proper response to vehicle-control actions by the flight trainee.

Additional cameras and terrain models would be used for re-entry and landing simulations. Special high-intensity projectors would simulate the sun and create realistic flash-blindness effects on a trainee.

MOSLEY
WWV
BEAM
ANTENNA



Offers up to 8 db. gain on 10, 15 and 20 mcs. to provide better reception of WWV and WWVH. 20 db. front-to-back signal ratio minimizes interference at locations between these two stations. Model WWV-33 Antenna is 100% rust-proof, built to withstand 150 mph winds.
Easily assembled and installed by non-technical personnel.

Mosley Electronics, Inc.
BRIDGETON, MISSOURI
WRITE FOR INFORMATION

AEROPHYSICS AND SPACE PROPULSION

ARMOUR RESEARCH FOUNDATION offers exceptional opportunities for unusually qualified engineers and scientists to join our Fluid Dynamics Research staff. We are seeking engineers and scientists with advanced degrees, demonstrated creative ability and a minimum of five years of research experience to initiate and direct research programs in:

MAGNETOHYDRODYNAMICS
ELECTRIC PROPULSION
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HEAT TRANSFER
MOLECULAR FLOW
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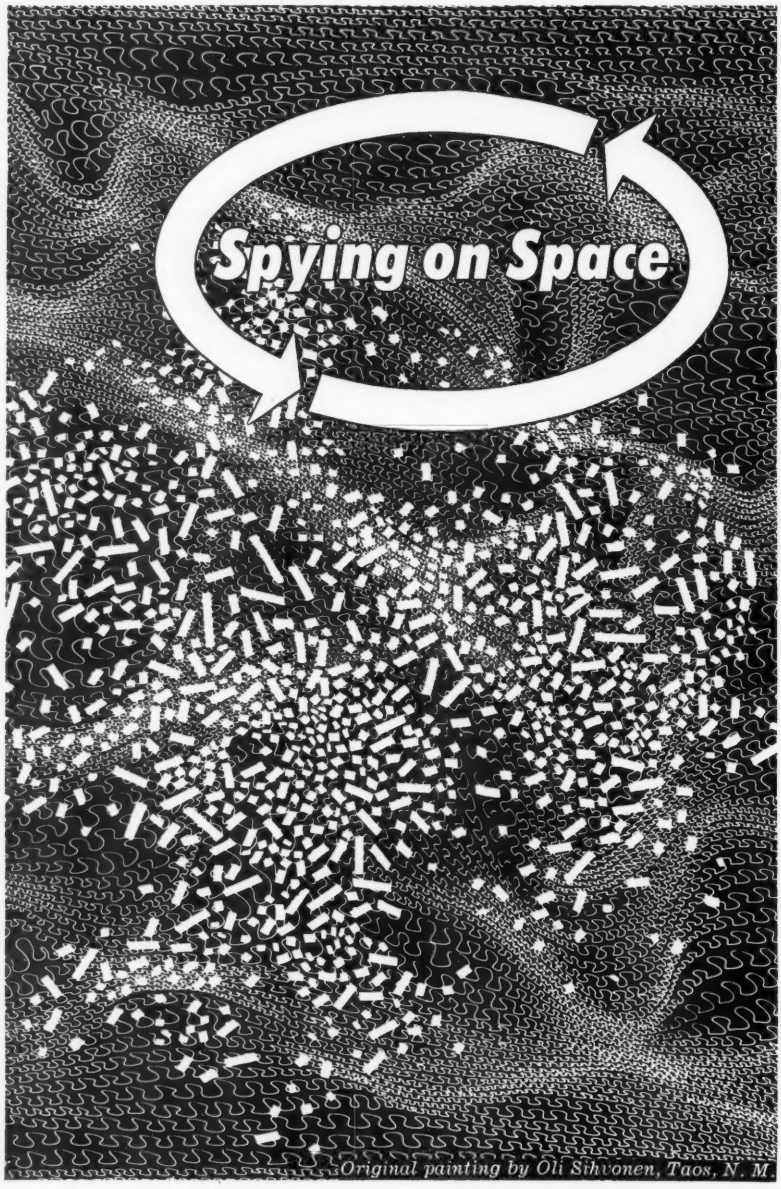
As a Foundation staff member there is opportunity to be associated with a mature independent research organization with a staff of over 600 engineers and scientists contributing to a wide variety of industrial and government research programs. Interested research workers please contact Dr. T. Paul Torda, Director of Fluid Dynamics and Systems Research, Department 2-S.

ARF
ARMOUR RESEARCH FOUNDATION
OF ILLINOIS INSTITUTE OF TECHNOLOGY
TECHNOLOGY CENTER, CHICAGO 16, ILL.



Original painting by Oli Sihvonen, Taos, N. M.

Through the use of tissue equivalent dose rate meters carried on various high altitude research rockets, Los Alamos scientists are learning much about radiation in space, including its possible effect on humans. The instruments simulate human tissue, observe the effects of radiation and telemeter the data back to earth.

For Employment Information Write:
Director of Personnel Division 61-23

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

People in the News

(CONTINUED FROM PAGE 90)

associate director of the center and as a senior scientist.

Earl D. Needham has been named director of material for Atomics International, a division of North American Aviation, succeeding **K. B. Gay,** who has been appointed to a similar position with NAA's Space and Information Systems Div.

Alfred H. Hobelmann has been appointed director of defense activities, Kidde Aero-Space Div., Walter Kidde & Co., Inc.

James N. Mellor has been appointed manager of manned vehicles and supporting systems, Republic Aviation, and **William P. Morris** will succeed Mellor as assistant Washington representative.

Gaelen L. Felt has been named manager, Las Vegas operations, of Edgerton, Germeshausen & Grier, Inc.

S. Edward Franklin has been named chief engineer, Klixon Precision Controls, Metals & Controls Inc., a division of Texas Instruments.

Douglass C. Harvey has been appointed associate director of research and engineering for Eastman Kodak's Apparatus and Optical Div.

William A. Rabe has been appointed manager of the new Surface Radar and Electronic Warfare Development Laboratory, Military Products Div., General Dynamics/Electronics. **David T. Blackstock** has been named a senior physicist at the Stromberg-Carlson Div.

John H. Boyle has been named general manager of Collins Radio Co.'s new Communication and Data Processing Div.; **James H. Green Jr.,** director of the Space Communications Div. of the Alpha Corp. subsidiary; and **Raymond V. Bruland,** manager of the Cedar Rapids division aviation product line.

Louis E. Hart has been appointed to the new post of manager of manufacturing engineering for Avco's Electronics and Ordnance Div.

HONORS

Malcolm R. Currie, Hughes Aircraft Co. scientist, has been named one of five "outstanding young men" of 1960 by the California Junior Chamber of Commerce for his contributions in the space propulsion and microwave electronics fields. Dr. Currie currently is manager of the physics laboratory at Hughes Research Laboratories. ♦♦

Compiled by C. P. King, *Materials and Process Section, The Marquardt Corp., Van Nuys, Calif.*

HEAT-TREATABLE ALUMINUM SHEET ALLOYS

Long used as a structural material in aircraft, aluminum sheet alloys are finding many applications in missiles. Although aluminum begins to suffer measurable loss of strength above 400 F, skin-cooling devices and careful selection of flight paths have enabled aluminum to continue as a missile material despite increasing temperatures.

Aluminum's principal advantages are its high strength-to-weight ratio, its ease of working and machining, its long history of applications and its low cost. An additional advantage has appeared recently with the increasing use of liquid hydrogen and oxygen in rocket systems. Most metals become intolerably brittle when subjected to cryogenic temperatures, but the aluminum alloys retain their ductility even down to liquid-hydrogen temperatures (−423 F).

Fabrication

All the aluminum alloys have excellent machinability. Forming of sheet may be performed by spinning, deep drawing, stretching, hydroforming, rubber forming, stamping or virtually any commonly used method. When working is severe, the annealed (−0) temper should be used. Less severe draws can be made on the X2020, 2219 and 2014 in the −W or −T4 temper, on 6061 in the −T4 temper, and on 7075 and 2024 in the −W temper. An aging treatment to follow forming can be employed to produce the desired temper.

Joining

Riveting remains the most popular method of joining aluminum sheet. Aluminum rivets having about the same strength as the material being joined are frequently used, though steel rivets are sometimes used where protection against galvanic corrosion can be provided.

The inert-gas-shielded-arc method is generally used for welding aluminum. Of the alloys discussed here, the 6061 alloy is readily weldable by fusion or resistance. The other alloys present difficulties and may require special techniques.

Oxidation and Corrosion Resistance

When aluminum alloys are exposed to air, they quickly form a protective film of oxide. This film is immeasurably thin but prevents further oxidation.

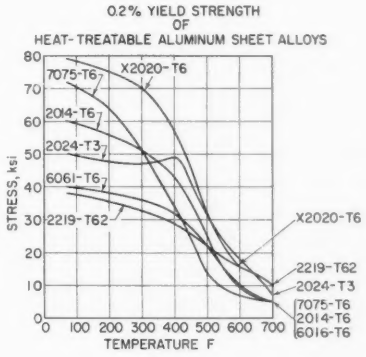
Dilute mineral acids, strong caustic solutions, and halogen-bearing salts have the most corrosive effect upon aluminum.

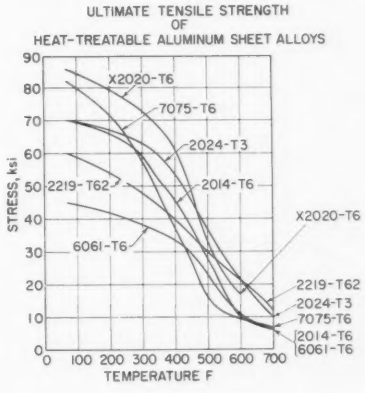
Many alloys are available in "Alclad" form, that is, coated with a thin layer of high-purity aluminum which provides very good resistance to corrosion.

Anodizing is a widely used means of protection which bestows exceptional wear-resistant and electrical-insulation characteristics. Paints, lacquers, resins and enamels are sometimes used where sheet gauges are too thin to permit the use of penetration coating and where touch-up capability is important.

Tensile Properties at −320 F

Alloy	UTS, psi	YS, psi	Elongation, %
2014-T6	84,000	69,000	14
2024-T3	91,000	84,000	5
6061-T6	56,000	45,000	24
7075-T6	99,000	86,000	9
X2020-T6	99,000	92,000	2
2219-T62	74,000	50,000	15





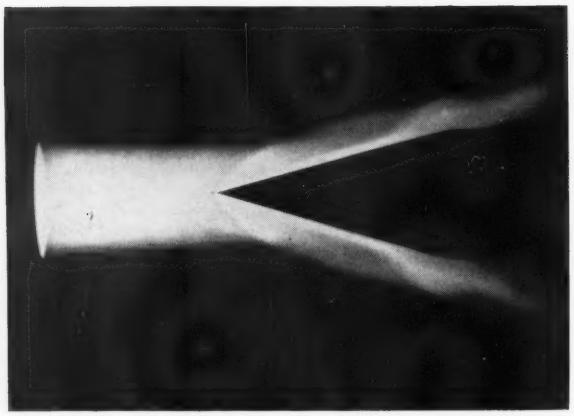
Nominal Chemical Composition (%)

Alloy	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Zr	Cd	Li	V
2014	0.9	1.0	4.5	0.8	0.5	0.25	0.1	0.15	—	—	—	—
2024	0.5	0.5	4.5	0.65	1.5	0.25	0.1	—	—	—	—	—
2219	0.2	0.3	6.0	0.3	0.02	0.10	—	0.06	0.15	—	—	0.1
6061	0.6	0.7	0.3	0.15	1.0	0.25	0.25	0.15	—	—	—	—
7075	0.5	0.7	1.6	0.3	2.5	5.7	0.25	0.2	—	—	—	—
X2020	—	—	4.5	0.5	—	—	—	—	—	0.2	1.1	—

Physical Properties

Alloy	Density, lb/in³	Coefficient of Thermal Expansion, 68 to 212 F	Thermal Conductivity, Btu at 77 F	Melting Range, F
2014-T6	0.101	12.8	1070	950 to 1180
2024-T3	0.100	12.9	840	935 to 1180
2219-T62	0.102	12.4	870	1010 to 1190
6061-T6	0.098	13.1	1070	1080 to 1200
7075-T6	0.101	13.1	840	890 to 1180
X2020-T6	0.098	12.8	609	975 to 1190

ADVANCED MATERIALS TESTING FACILITIES



Now available for evaluation of
High Temperature Materials Applications

Re-entry nose cone studies and radiation-equilibrium studies consisting of leading edges and other structural components of high altitude glide vehicles are now being performed in the materials test facilities at Plasmadyne using a plasma arc device to simulate free-flight conditions. Run durations range from a **few seconds** (for strongly ablating plastic models at high heat flux values) to more than **one hour** for glide vehicle components. Low contamination levels of less than 0.1% have been attained with properly designed water-cooled metal electrodes. Space-wise uniformity of the jet has been determined by surveys with pitot probes, cold-wall calorimeters and total enthalpy probes designed and developed at Plasmadyne. Model exterior and interior temperature readings and complete color film coverage are offered as part of the test program along with an extensive test report which includes model test data, film footage, calibration data, and a description of the facility.

- **GLIDE VEHICLE AND NOSE CONE STUDIES**
- **FREE FLIGHT MACH NUMBERS 6 TO 22**
- **ALTITUDE SIMULATION — 100,000 TO 350,000 FT.**
- **VELOCITY SIMULATION — 7000 FT/SEC. TO 35,000 FT/SEC.**
- **STAGNATION ENTHALPY FROM 1500 BTU/LB. TO 25,000 BTU/LB.**
- **MATERIAL SAMPLE SIZES TO 3" DIAMETER (6" IN NEAR FUTURE)**
- **CONTINUOUS TEST RUNS UP TO 2 HOURS FOR PROGRAMMED TRAJECTORY SIMULATION**
- **DETAILED CALIBRATION OF FLOW PARAMETERS**
- **LESS THAN 0.1% CONTAMINATION**

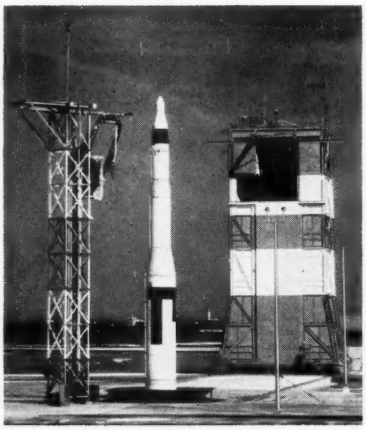
For further information contact Miss S. L. Grindle, Manager, Materials Test and Evaluation Group.

plasmadyne
A SUBSIDIARY OF GIANNINI SCIENTIFIC CORPORATION
3839 South Main Street, Santa Ana, Calif.

Centaur Pad Nears Completion

View from associated 17-story tower shows pad nearing completion at AMR, Cape Canaveral, Fla., for Atlas-Centaur flight testing. Part of Space Complex 36, the pad features a concrete blast deflector not requiring water cooling.

Up for ICBM History



The first flight-test Minuteman—all stages and guidance live—sits on the pad at Cape Canaveral ready for its successful maiden launch February 1. The test missile measures 58 ft and weighs about 66,000 lb, including a 1000-lb instrument section just above the third stage. It is chiefly this section that distinguishes the flight-test from the planned operational missile.

ARS Space Flight Report to the Nation

OCTOBER 9—14, 1961

Application For Hotel Accommodations

Please fill out this application form completely and mail it to:

Miss Sylvia Peltonen, Secretary
ARS Housing Committee
90 East 42 Street
New York 17, N. Y.

HOTEL	SINGLE	DOUBLE	TWIN BEDS
ABBEY, 151 West 51st St.	8.00- 9.00	10.50-12.50	12.50-14.50
*BARBIZON-PLAZA, 106 Central Pk. So.	13.50-15.50		17.50-21.50
*BARCLAY, 111 East 48th St.	15.50-21.50		23.50-27.50
*BELMONT PLAZA, Lexington Ave. & 49th St.	8.50-16.00	14.00-19.00	16.00-20.00
*BILTMORE, Madison Ave. & 43rd St.	8.00-20.00	15.00-25.00	15.00-25.00
*COMMODORE, Lexington Ave. & 42nd St.	8.50-16.50	14.00-20.50	15.00-23.00
*DIXIE, 250 W. 43rd St.	9.00-12.00	12.00-15.00	13.00-17.00
*EDISON, 228 W. 47th St.	8.00-11.00	13.00-18.00	15.00-21.00
*ESSEX HOUSE, 160 Central Park So.		22.00	22.00
*GOVERNOR CLINTON, 7th Ave. & 31st St.	10.00-14.00	14.00-20.00	14.00-20.00
*HENRY HUDSON, 353 W. 57th St.	8.00-11.00	12.00-16.00	13.00-18.50
*MANGER VANDERBILT, Park Ave. & 34th St.	8.50-21.00	13.00-21.00	15.50-21.00
*MANHATTAN, 8th Ave. & 44th St.	9.00-14.00	14.00-18.00	15.00-18.50
*MAYFLOWER, Central Pk. W. & 61st St.	12.00-16.00		14.00-17.50
NEW YORKER, 8th Ave. & 34th St.	8.00-14.50	11.50-18.00	15.50-20.00
PARAMOUNT 235 West 46th St.	8.00- 9.00	10.00-12.00	12.00-14.00
PARK LANE, 299 Park Ave.	19.00	24.00	24.00
*PARK-SHERATON, 7th Ave. & 55th St.	11.00-16.00		15.00-20.00
*PIERRE, 2 East 61st St.			24.00-30.00
*PLAZA, 5th Ave. & 59th St.			23.00-30.00
*ROOSEVELT, Madison Ave. & 45th St.	8.50-20.00	13.50-24.00	17.50-25.00
*ST. MORITZ, 50 Central Park So.	13.00-16.00		16.00-20.00
*SAVOY HILTON, 5th Ave. & 58th St.	19.00		23.00
*SHERATON-ATLANTIC, Broadway & 34th St.	9.00-14.00	13.00-17.00	14.00-18.00
*SUMMIT, Lexington & 51st St.	14.00-30.00	16.00-32.00	18.00-34.00
TAFT, 7th Ave. & 50th St.	10.75		17.50
VICTORIA, 7th Ave. & 51st St.	9.00- 9.50	12.50-13.00	14.50-16.00
*WALDORF-ASTORIA, 301 Park Ave.	12.00-20.00	18.00-28.00	18.00-28.00
*WARWICK, 65 West 54th St.	18.00		22.00
*WELLINGTON, 7th Ave. & 55th St.	8.50-12.50	13.00-18.00	13.00-18.00
WOODSTOCK, 127 W. 43rd St.	7.00- 9.00	10.00-14.00	10.00-14.00

Rates subject to 5% New York City tax on hotel rooms. *Suites available. For reservations contact housing bureau.

----------CUT ALONG THIS LINE----------

Hotel Accommodations Desired. (It is necessary that five choices of hotels be listed below:)

INDICATE APPROXIMATE RATE AS SHOWN IN SCHEDULE		TYPE OF ROOM DESIRED		
CHOICE	HOTEL	SINGLE 1 PERSON	ONE DOUBLE BED— 2 PERSONS	TWIN BEDS 2 PERSONS
1st				
2nd				
3rd				
4th				
5th				

If accommodations are not available at any of the above hotels, reservations will be made at some other suitable hotel.

NAME.....

AFFILIATION.....

ADDRESS (Home/Bus.).....

CITY..... STATE.....

DATE ARRIVING..... ARRIVAL HOUR..... DATE DEPARTING.....

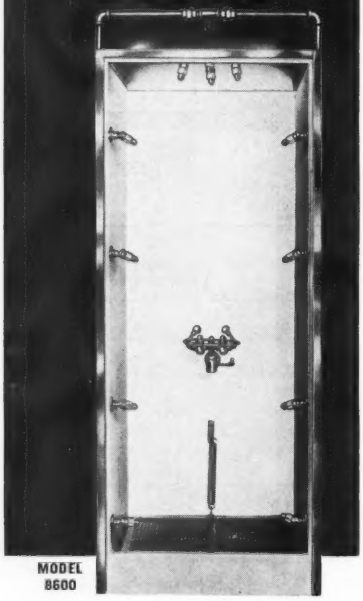
Please list names, affiliations and desired accommodations for additional persons on separate sheet and attach to this form.

NOTE: There will be an interval of several weeks before you can expect to receive a direct confirmation from the hotel accepting your reservation. Room numbers cannot be assigned by hotels until guests register on arrival.

MAKE YOUR RESERVATION NOW

Volatile chemicals and propellants can cause serious accidents—but serious injuries need not result if water irrigation is immediately available! Haws Decontamination Booth provides the "cloudburst" that rapidly rids the body of harmful irritants. Victims walk on the foot treadle and are instantly bathed in water from a dozen nozzles. Haws Eye-Face Wash is simultaneously activated—a pressure controlled unit with a perforated face-spray ring and twin eye-wash heads. Booth is acid resisting fiberglass plastic, and is delivered complete, ready for tie-in to existing facilities. Write for details on the full line of models.

HAWS DECONTAMINATION BOOTH



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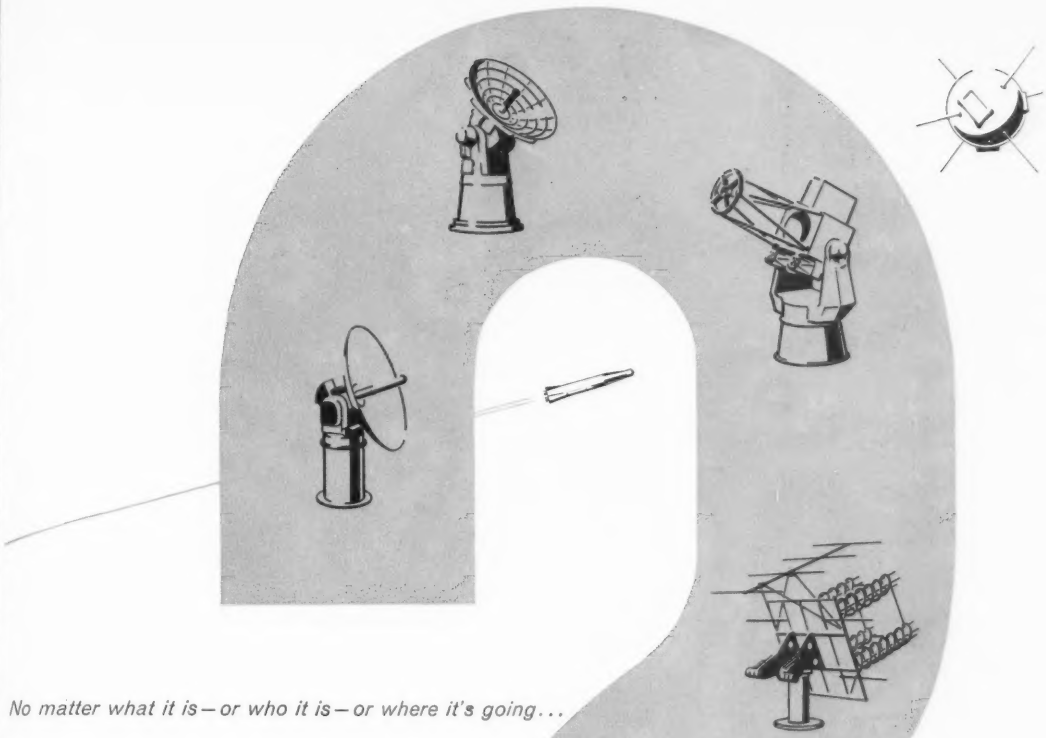

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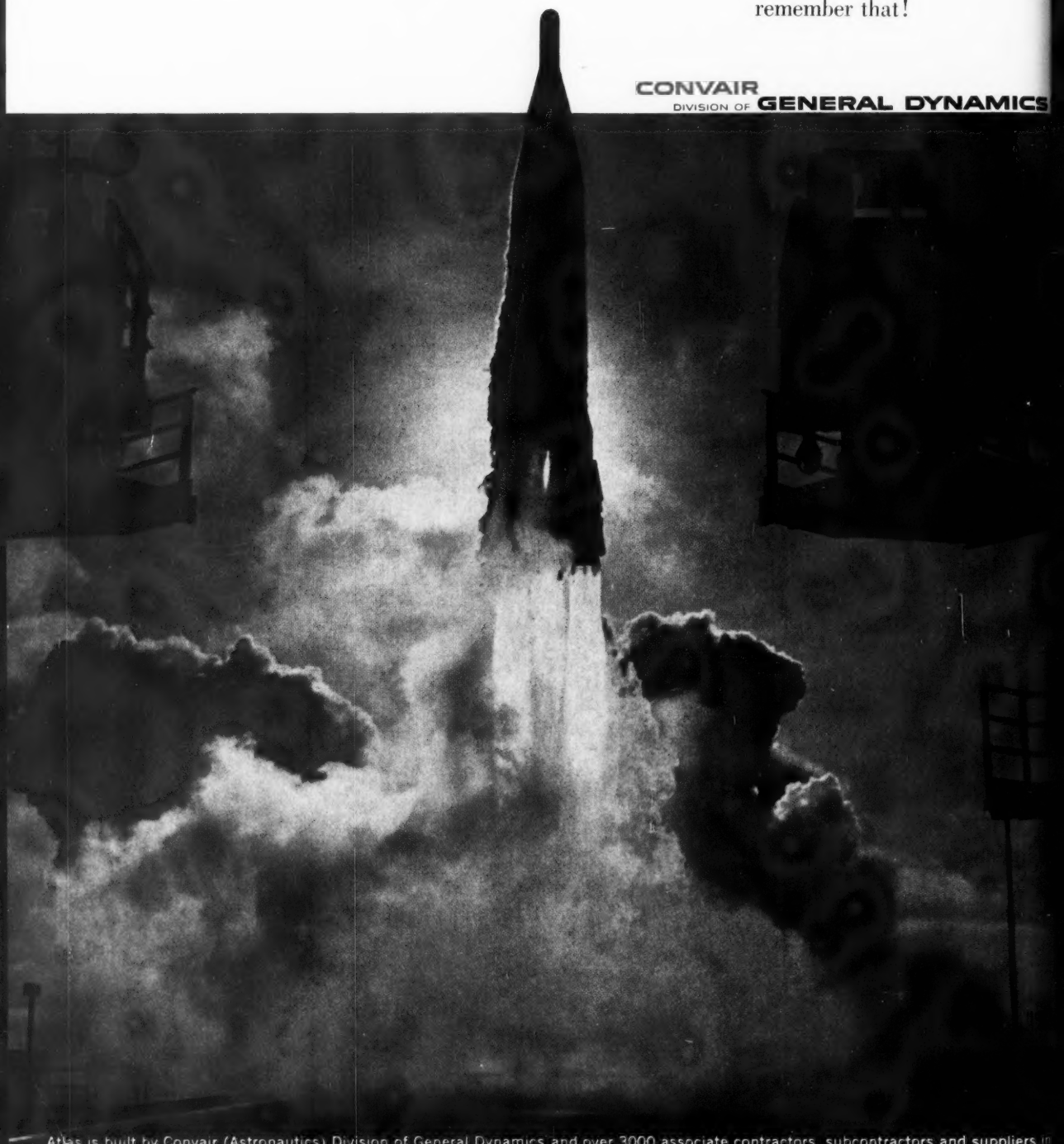
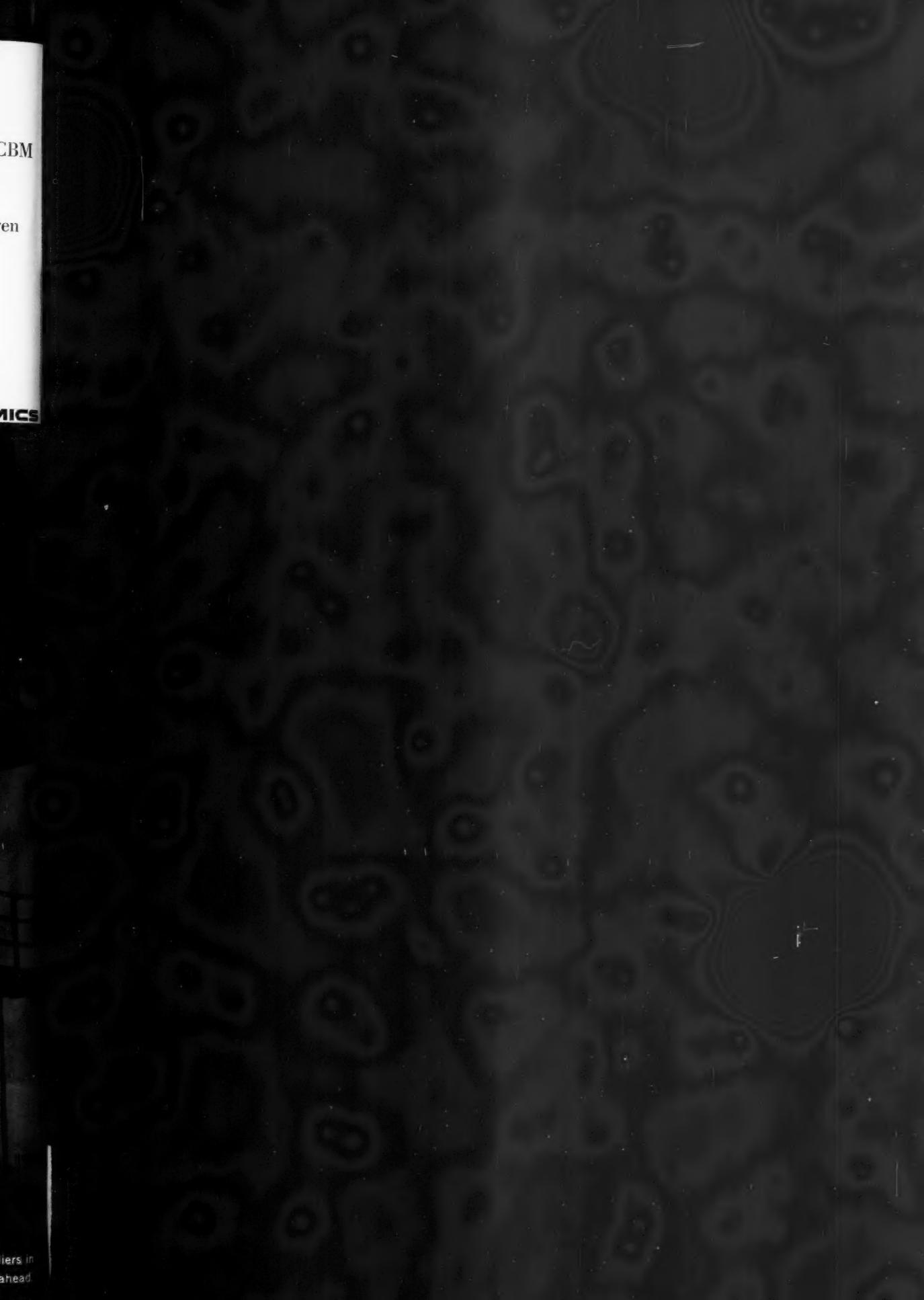
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